

Acknowledgements



Photo: Robin McLeod

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Canada

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- FOCAerie (Federation of Conservation Authorities of Lake Erie)
- Health Canada
- Ontario Ministry of Agriculture and Food
- Ontario Ministry of the Environment
- Ontario Ministry of Natural Resources

United States

- Michigan Department of Environmental Quality
- New York State Department of Environmental Conservation
- National Oceanic and Atmospheric Administration
- Ohio Department of Natural Resources
- Ohio Environmental Protection Agency
- Pennsylvania Department of Environmental Protection
- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- U.S. Geological Survey

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- Great Lakes Fishery Commission
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In keeping with the spirit of binational cooperation, the reader will note the alternation between Canadian and U.S. preferred spelling on a number of occasions.



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Introduction

Photo: U.S. EPA Great Lakes National Program Office



One of the most significant environmental agreements in the history of the Great Lakes took place with the signing of the Great Lakes Water Quality Agreement of 1978 (GLWQA) between the United States and Canada. This historic agreement committed the U.S. and Canada (the Parties) to address the water quality issues of the Great Lakes in a coordinated, joint fashion. The purpose of the GLWQA is to “restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem.” Paramount to this goal was the protection of human health.

In the revised GLWQA of 1978, as amended by Protocol signed November 18, 1987, the Parties agreed to develop and implement, in consultation with State and Provincial Governments, Lakewide Management Plans (LaMPs) for lake waters and Remedial Action Plans (RAPs) for Areas of Concern (AOCs). The LaMPs are intended to identify critical pollutants that impair beneficial uses in the lake proper and to develop strategies, recommendations and policy options to restore these beneficial uses. Moreover, the Specific Objectives Supplement to Annex 1 of the GLWQA requires the development of ecosystem objectives for the lakes as the state of knowledge permits. Annex 2 further indicates that the RAPs and LaMPs “shall embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses...they are to serve as an important step toward virtual elimination of persistent toxic substances....”

The Great Lakes Water Quality Agreement specifies that the LaMPs be completed in four stages. These stages are: 1) when problem definition has been completed; 2) when the schedule of load reductions has been determined; 3) when remedial measures are selected; and 4) when monitoring indicates that the contribution of the critical pollutants to impairment of beneficial uses has been eliminated. These stage descriptions suggest that the LaMPs are to focus solely on the impact of critical pollutants to the lakes. However, the group of government agencies designing the LaMPs felt it was also an opportunity to address other equally important issues in the lake basins. Therefore, the LaMPs go beyond the requirement of a LaMP for critical pollutants and use an ecosystem approach, integrating environmental protection and natural resource management.

The LaMP process has proven to be a resource intensive effort and has taken much longer than expected. In the interest of advancing the rehabilitation of the Great Lakes, and getting more information out to the public in a timely manner, the Binational Executive Committee (BEC) passed a resolution in 1999 to accelerate the LaMP effort (BEC 1999). By accelerate, it

was meant that there should be an emphasis on taking action and adopting a streamlined LaMP review and approval process. The LaMPs should treat problem identification, selection of remedial and regulatory measures, and implementation as a concurrent, integrated process rather than a sequential one.

The BEC endorsed application of the concept of adaptive management to the LaMP process. The LaMPs employ a dynamic process with iterative elements, such as periodic reporting. Adaptive management allows the process to change and build upon lessons learned, successes, new information, changes in the lake and public input. The LaMP will adjust over time to address the most pertinent issues facing the lake ecosystems.

Working under the adaptive management concept, the BEC recommended that a LaMP be produced for each lake by April 2000, with updates every two years thereafter. The LaMPs were to be based on the current body of knowledge and state what remedial actions can be implemented now. Consistent with the BEC resolution, the Lake Erie LaMP 2000 was presented in a loose-leaf format with general tabbed sections that could be inserted into a three-ring binder. This format allowed the LaMP to be viewed as a working draft of the dynamic LaMP process and adding new material and removing outdated information could easily update the document. However, in 2002, rather than updating the LaMP 2000 binder, a separate stand-alone progress report was produced.

For 2004, aspects of the LaMP 2000 and LaMP 2002 are combined to better reflect the BEC concept of one working draft.

The document is slightly reformatted to better accommodate updates on LaMP progress as well as maintain documentation of the main history that formed the baseline and direction of the LaMP. It will truly become “The Lake Erie LaMP,” an ever-changing accounting of the goals and progress of the Lake Erie LaMP process.

The GLWQA directs that the LaMPs take an ecosystem approach to assessing problem definition and implementing remedial actions. This concept is evident throughout the Lake Erie LaMP. The environmental integrity of Lake Erie is dependent not only on various characteristics and stressors within the lake itself, but also on actions implemented throughout the Lake Erie watershed and beyond. Urban sprawl, shoreline development, climate change, the introduction of non-native invasive species, the use and destruction of natural lands and resources, the dominant agricultural and industrial practices within the lake basin, and long-range transport of contaminants from outside the basin all impact the health of Lake Erie.

The watershed approach has been widely accepted as a necessary practice to achieve environmental restoration and protection. Many of the RAPs take a watershed approach to restoring the beneficial uses impaired in their AOCs. The TMDL program in the U.S. uses a watershed approach to return all impaired streams to their designated use. Many other communities around Lake Erie have instituted watershed-planning efforts focused on improving their local waterways. The challenge of the LaMP is to extend those watershed-planning efforts to include a lake effect component as well. Some watersheds, such as the Maumee (OH) and the Grand (ON), have a more direct impact on Lake Erie than others, but in the big picture all tributaries ultimately contribute to lake conditions in some way. Conversely, some conditions in the lake (i.e. non-native invasive species, contaminants, water levels, etc.) may also be impacting the tributaries.

The LaMP provides a binational structure for addressing these environmental and natural resource issues, coordinating research, pooling resources, and making joint commitments to improve the environmental quality of the Lake Erie. The Lake Erie LaMP is a program in which ongoing efforts, some of which may be conducted independently of the LaMP, can be strategically synthesized. Some of these actions include: the State of the Lakes Ecosystem



Conference (SOLEC) efforts to develop Great Lakes indicators; the Lake Erie Millennium Network initiative to identify, prioritize and pursue research needs; the efforts of Canadian and U.S. conservation agencies in controlling non-point sources and agricultural land use management; the land acquisition and preservation efforts of environmental groups such as The Nature Conservancy and the Nature Conservancy of Canada; the pollution prevention based activities of the Great Lakes Binational Toxics Strategy; implementation of the Remedial Action Plans in the 12 Lake Erie areas of concern; the fishery management plan of the Great Lakes Fishery Commission's Lake Erie Committee; implementation of wildlife management plans; and the efforts of the Lake Erie Binational Public Forum and others encouraging stakeholders across the basin to become involved in the decision-making process to determine the future status of Lake Erie. The LaMP remains mindful of emerging issues that may need to be adapted into the LaMP management scheme.

The Lake Erie LaMP focuses on measuring ecosystem health, teasing out the stressors responsible for impairments, and evaluating the effectiveness of existing programs in resolving the stress by continuing to monitor the ecosystem response. The role of the LaMP, as a management plan, is to define the management intervention needed to bring Lake Erie back to chemical, physical and biological integrity, and to further define agency commitments to those actions. Although Environment Canada (EC) and the U.S. Environmental Protection Agency (U.S. EPA) are the lead agencies for the LaMP, it takes an array of federal, local, state and provincial agencies and stakeholders to successfully design and implement the Lake Erie LaMP.



Section 1: Executive Summary

Working under the adaptive management concept, the Binational Executive Committee (BEC) recommended that a LaMP be produced for each lake by April 2000, with updates every two years thereafter. Consistent with the BEC resolution, the Lake Erie LaMP 2000 was presented in a loose-leaf format, with general tabbed sections, that could be inserted into a three-ring binder. This format allows the LaMP to be viewed as a working document, easily adding new material and removing outdated information as needed.

It is important to understand that the Lake Erie LaMP is a management plan and not a state of the lake report. Biennial updates are meant to measure the progress under the LaMP work plan or present the results of research or assessment reports that were undertaken or initiated by or in collaboration with the Lake Erie LaMP. This revised document does not include reference to all actions that have occurred in the Lake Erie watershed since the 2004 report.

The Lake Erie LaMP has compiled and assessed a significant amount of information to determine the current problems in the lake, their sources, and the ecosystem objectives that must be achieved if the Lake Erie LaMP vision is to be obtained. It is now time to focus on implementation. What actions or programs are most important to protect and restore the lake? Who has the authority to implement those actions? Is additional funding needed and, if so, where will it come from? Is the LaMP management structure sufficient to achieve the Lake Erie vision? The LaMP work plan for the next two years will address these questions.

Section 1:
Executive Summary

1



Photo: Upper Thames River Conservation Authority

The Lake Erie LaMP must finalize measurable indicators that identify the current state of the ecosystem relative to the desired state of the ecosystem, as described by the Lake Erie Vision and ecosystem management objectives. The Indicators Task Group has prepared an indicator matrix to better understand and organize the application of the proposed indicators. The matrix structure is based on the five habitat zones identified for the Lake Erie basin. The indicators are divided into two categories: pressure (including the management objectives and processes) and state. The matrix has been populated by candidate indicators proposed by respondents to a questionnaire. The next step is to refine the list of candidate indicators using selection criteria defined by the Task Group. The result will be a suite of indicators that meet the needs of the Lake Erie LaMP.

Concentrations of selected contaminants in bed sediment were further summarized. Results support the understanding that high levels of trace element and PAH contamination are not systemic throughout the basin (in both tributaries and open lake), but co-located with source areas such as urban-industrialized areas, creosote production and petroleum processing and refining. Median concentrations for all the trace elements were below threshold effect concentrations (TEC). Organochlorine pesticides (DDT, dieldrin, mirex, lindane, chlordane, hexachlorobenzene) and PCBs continue to persist in the sediments although they are detected less frequently than trace elements or PAHs. Localized high concentrations of these chemicals exist, but the median concentration never exceeded TEC.

Although considered inadequate to calculate total loadings to the Lake Erie Basin, evaluation of the U.S. Toxic Release Inventory (TRI) and the Canadian National Pollutant Release Inventory (NPRI) was done to estimate the amount of mercury released in the basin and the top contributing sources. From 1995 to 2003, over 69,000 kg (151,800 lbs) of mercury were reported released, primarily to air and onsite landfills or transferred to offsite sewage treatment plants. Waste management companies, electric services and chlor-alkali plants were the main contributors. Estimates for PCBs were done only for the U.S. as PCBs are not reported to the NPRI. For the same time period, over 758,000 kg (1.7 million lbs) of PCBs were released, 99% of which went to onsite landfills. The top contributor was waste management companies.

Per the recommendations of the Lake Erie LaMP Habitat Strategy, a project is underway to develop a unified, consensus-based habitat classification system and an associated geospatial database that integrates classification systems at relevant scales into map layers. The goal is to create a binational GIS-based habitat map. Several workshops have been held to involve the technical experts and managers. Testing and validation is planned for the Maumee River and Grand River watersheds, after which the project will be expanded to the rest of the Lake Erie basin.

Other habitat projects underway include: an assessment of coastal wetlands around Rondeau Bay (Ontario Ministry of Natural Resources); the Fort Malden shoreline stabilization/habitat enhancement project and the McKee Park habitat enhancement project (Essex Region Conservation Authority); and the Middle Harbor fish habitat restoration project (Ohio Department of Natural Resources). The Huron-Erie Corridor system habitat assessment is creating a framework and designing a process to identify, coordinate and implement aquatic habitat restoration opportunities in the Lake Huron to Lake Erie Corridor. The Huron-Erie Corridor project is being conducted within the context of long-term water level regime changes resulting from direct hydro-modification and/or potential effects of global climate change. USGS completed the Ohio Aquatic GAP analysis project in 2005. Seventy-five (15%) of 504 14-digit hydrologic sub-watershed units in the Lake Erie basin were identified as having high potential for priority conservation. Thirty-seven of the 75 sub-watersheds already include some conservation lands within their boundaries.

From a human health perspective, as required by legislation passed stemming from the Walkerton, Ontario situation, watershed plans to protect drinking water sources are being developed in Ontario. On the U.S. side, the passage of the Beaches Environmental Assessment and Coastal Health Act (BEACH Act) in 2000 has done much to standardize criteria for beach postings, improve sampling methodology and frequency, and improve communication to the public concerning the water quality at public beaches. In 2005, 33 of the 66 beaches monitored along the U.S. shoreline had at least one day when beaches were posted.

Updates are included on the progress of 12 RAPs and seven watershed initiatives around Lake Erie. Each update provides a short history of the process and past actions, progress since the 2004 LaMP report and next steps. A matrix summarizing each area is included for the first time. These reports indicate continuing interest and participation in RAP and watershed programs. The involvement of local groups and agencies is a critical component in the success of restoring beneficial uses to these areas and to ultimately reduce impacts on the lake.

Since the late 1970s, concentrations of PCBs, DDT and mercury have generally declined in Lake Erie walleye, smelt and lake trout, although a fair degree of variability is seen from year to year. Over the sampling period, no fish have ever exceeded GLWQA criteria for DDT

or mercury (1.0 µg/g and 0.5 µg/g, respectively). PCBs in walleye and lake trout consistently exceed the GLWQA of 0.1 µg/g, while rainbow smelt hover near or below the criteria.

Photo: Upper Thames River Conservation Authority



In the last decade, in-lake concentrations of phosphorus have been on the rise. Hypoxia and anoxia in the central basin are more extensive and occurring earlier in the summer, while *Microcystis* blooms and *Cladophora* growth have been observed recently to rival those of the 1970s. These signs all suggest that Lake Erie is out of trophic control once again. Lake Erie was monitored in 2004 under the U.S and Canada collaborative comprehensive survey (ECCS) with the next round planned for 2009. Sampling was focused on observing key physical and water quality measurements, nearshore/offshore exchanges and the impacts of zebra and quagga mussels. In 2005, under the International Field Year on Lake Erie (IFYLE) program, research/monitoring was done to gather information to help forecast the onset, duration and extent of hypoxia and harmful algal blooms across the basin and to assess the ecological consequences of hypoxia on the food web. While the results of these studies are still forthcoming, many hypotheses implicate zebra and quagga mussels as a major cause of the lake's current problems. Long-term tributary monitoring work conducted by the National Center for Water Quality Research at Heidelberg College suggests a trend of increasing concentrations and loads of sediments and nutrients from the monitored tributaries in Michigan and Ohio. Of particular interest is the increase in the amount of dissolved reactive phosphorus as it is the most bioavailable form of phosphorus.

In the fall of 2005, hydrogen sulfide gas was released from the hypolimnion during the fall turnover. The extent of this release ranged from Cleveland to Buffalo and was so pervasive as to be investigated by emergency response teams in Pennsylvania as a gas leak, sewage discharge or chemical explosion. However, monitoring buoys installed by NOAA under IFYLE verified that this was indeed a phenomenon associated with lake turnover. Under the appropriate weather conditions, and if anoxia continues to move closer to shore, we can anticipate seeing this situation repeat itself more frequently.

The Lake Erie LaMP process is changing from assessment to implementation. For the next two years the LaMP will be reviewing its management structure and better identifying those actions that need to be taken on a lakewide basis or at the watershed level to obtain the ecosystem objectives set by the LaMP.

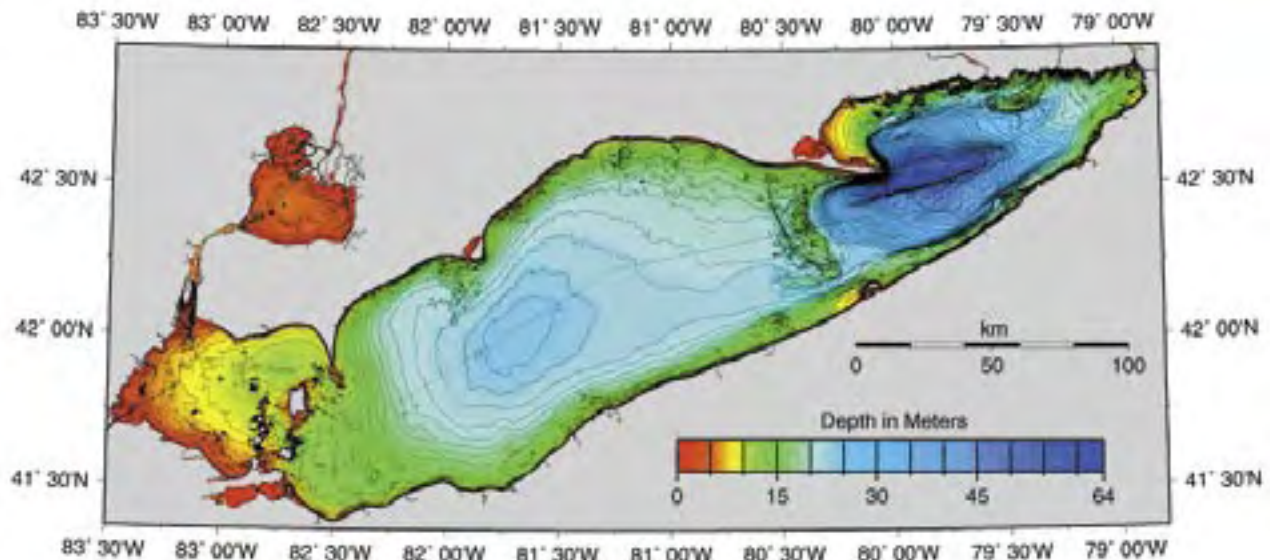
Section 2: Overview

2.1 Introduction to Lake Erie

The physical characteristics of Lake Erie have a direct bearing on how the lake ecosystem reacts to various stressors. By volume it is the smallest of the Great Lakes, and next to smallest in surface area. As the shallowest of the Great Lakes, it warms quickly in the spring and summer and cools quickly in the fall. During long, cold winters, a large percentage of Lake Erie is covered with ice, and occasionally it freezes over completely. Conversely, in warmer years, there may be no ice at all. The shallowness of the basin and the warmer temperatures make it the most biologically productive of the Great Lakes.

Lake Erie is naturally divided into three basins (Figure 2.1). The western basin is very shallow having an average depth of 7.4 metres (24 ft.) and a maximum depth of only 19 metres (62 ft.). The central basin is quite uniform in depth, with the average depth being 18.3 metres (60 ft.) and the maximum depth 25 metres (82 ft.). The eastern basin is the deepest of the three with an average depth of 25 metres (82 ft.) and a maximum depth of 64 metres (210 ft.). The central and eastern basins thermally stratify every year, but stratification in the shallow western basin is rare and very brief, if it does occur. Stratification impacts the internal dynamics of the lake, physically, biologically and chemically. These physical characteristics cause the lake to function as virtually three separate lakes.

Figure 2.1: Bathymetry of Lake Erie illustrating that the lake is comprised of three distinct basins, primarily defined by depth



Lake Erie's long narrow orientation parallels the direction of the prevailing southwest winds. Strong southwest winds and strong northeast winds set up extreme seiches, creating a difference in water depth as high as 4.3 metres (14 ft.) between Toledo and Buffalo (Hamblin, 1979). The effect is most spectacular in the western basin where large areas of the lake bottom are exposed when water is blown to the northeast, or large areas of shoreline are flooded as water is blown to the southwest. Overall current and wave patterns in Lake Erie are complex, highly changeable and often related to wind direction (Bolsenga and Herdendorf, 1993).

Eighty percent of Lake Erie's total inflow of water comes through the Detroit River. Eleven percent is from precipitation. The remaining nine percent comes from the other tributaries flowing directly into the lake from Michigan, Ohio, Pennsylvania, New York

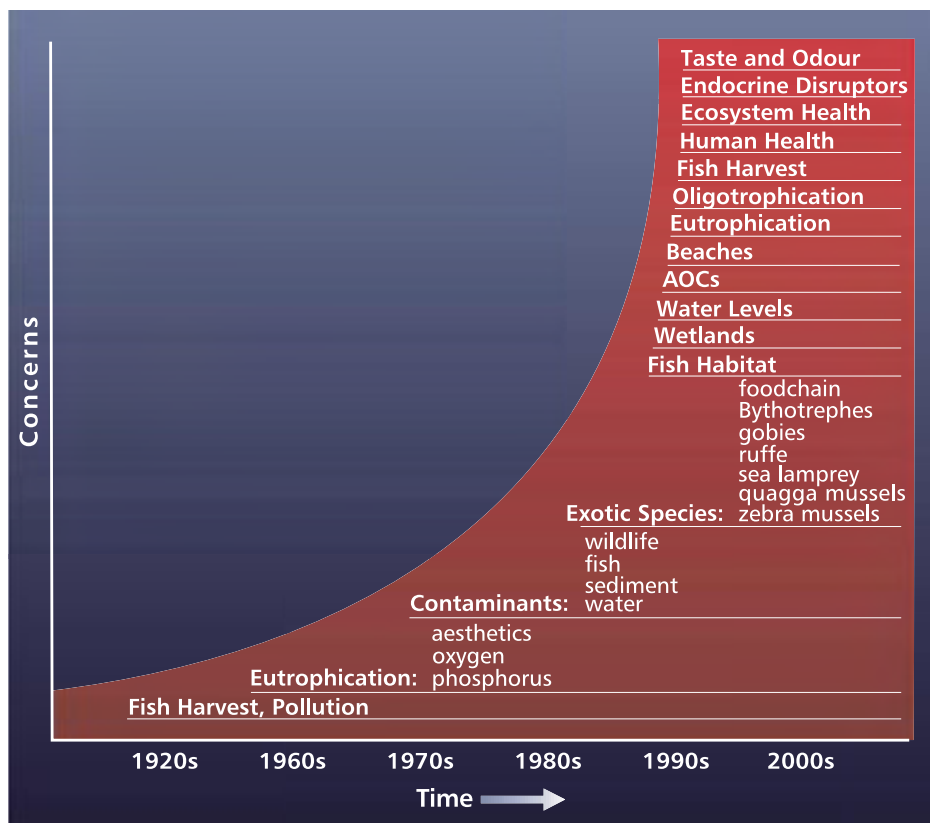
and Ontario (Bolsenga and Herdendorf, 1993). The Niagara River is the main outflow from the lake.

About one-third of the total population of the Great Lakes basin resides within the Lake Erie watershed. This amounts to 11.6 million people (10 million U.S. and 1.6 million Canadian), including 17 metropolitan areas, each with more than 50,000 residents. The lake provides drinking water for 11 million people.

Of all the Great Lakes, Lake Erie is exposed to the greatest stress from urbanization, industrialization and agriculture. Reflecting the fact that the Lake Erie basin supports the largest population, it surpasses all the other Great Lakes in the amount of effluent received from sewage treatment plants (Dolan, 1993). Lake Erie is also the Great Lake most subjected to sediment loading. Intensive agricultural development, particularly in southwest Ontario and northwest Ohio, contributes huge sediment loads to the lake. The Detroit River delivers sediment from the actively eroding shoreline of southeastern Lake Huron and Lake St. Clair. Long stretches of the Lake Erie shoreline experience episodes of active erosion, particularly during storms and periods of high water. The western basin is generally the most turbid region of the lake, and much of its sediment load eventually moves into the central and eastern basins. Suspended sediment can be considered a pollutant in itself, one that has profoundly influenced the ecology of the western basin and the river mouths of most of the Lake Erie tributaries. Most of the lake bottom is covered with fine sediment particles that are easily disturbed when the shallow lake is stirred up by winds.

Over the years, as use of the lake and land use around the basin changed, so too did the issues of concern in Lake Erie. The most important issues and the timeframe during which they appeared are illustrated in Figure 2.2. It is interesting to note how some of the issues recur, albeit due to different reasons. Commercial overfishing, pollution and habitat destruction began to take a toll in the late 1800s, and popular commercial fish populations plummeted. Many of the drinking water intakes for the major populated areas were moved far offshore to avoid epidemics of waterborne diseases, such as typhoid, resulting from raw sewage discharge. Nuisance conditions, floating debris, and odors were increasingly common.

Figure 2.2: Changing issues in Lake Erie over time



Lake Erie was the first of the Great Lakes to demonstrate a serious eutrophication problem. Its shallow nature made it the warmest and most biologically productive of the Great Lakes, but increased nutrient loadings beginning in the 1950s made it too productive. Results of this accelerated eutrophication were unhealthy, unattractive and odiferous. Algal blooms caused thick green and blue-green slicks on the water surface; turbidity increased due to more algae and suspended sediment in the water column; and excess *Cladophora*, a long, green, filamentous algae, covered the shoreline in slimy masses and mounded up on beaches when it died. A result of this increased productivity was oxygen depletion in the bottom waters of the lake as algae died, settled to the bottom and decomposed. The central basin is particularly susceptible to oxygen depletion because summer stratification forms a relatively thin hypolimnion at the bottom that is isolated from oxygen-rich surface waters. Oxygen is rapidly depleted from this thin layer as a result of decomposition of organic matter. When dissolved oxygen levels reach $<1\text{mg/l}$, the waters are considered to be anoxic. In addition to stressing and/or eliminating biological communities, anoxia changes chemical processes on the bottom, regenerating phosphorus from the sediments and recycling it back into the water column.

Accelerated eutrophication spanned the 1950s to the 1970s, with much of the central basin becoming anoxic. Phosphorus was deemed to be the main culprit (Burns, 1985). A comprehensive binational phosphorus reduction strategy was implemented to reduce phosphorus discharge from wastewater treatment plants, limit the use of phosphorus-containing detergents in the watershed, and to develop and encourage the use of best management practices to reduce phosphorus runoff from agricultural operations.

Increased industrialization and the formulation of new chemicals to aid in pest control led to concern about contaminants and the accumulation of persistent toxic chemicals in water, sediment, fish and wildlife. The development of extensive pollution control regulations, improvements in treatment technologies, adoption of stringent water quality standards, bans on production and use of certain chemicals, waste minimization and pollution prevention have

greatly reduced the direct discharge of contaminants. However, the lingering effects of these historic discharges, such as contaminated sediments and fish consumption advisories, and a greater public awareness of the environment raised further concerns about contaminants in the late 1970s that has continued to the present.

Efforts to restore lake trout, the extirpated top-predator in the cold waters of the eastern basin, were thwarted in the late 1970s and early 1980s by mortality caused by the non-native invasive sea lamprey. Sea lamprey invaded Lake Erie and the upper Great Lakes

after the Welland Canal was expanded in the early 1900s (Eshenroder and Burnham-Curtis 1999). Their abundance increased during the 1970s to the point that control efforts were implemented beginning in 1986.

The introduction of zebra mussels in the late 1980s triggered a tremendous ecological change in the lake. Zebra mussels have changed the habitat in the lake, altering the food web dynamic, energy transfer and how nutrients and contaminants are cycled within the lake ecosystem. Additional non-native invasive species such as the quagga mussel, goby, and several large zooplankton species have further complicated the system.



Photo: U.S. EPA Great Lakes National Program Office

In the 1990s, changing fish populations fueled a whole new debate on phosphorus loading. Lake Erie had essentially achieved the phosphorus levels established under the Great Lakes Water Quality Agreement as those needed to eliminate the effects of eutrophication. However, the models used to determine the maximum allowable annual phosphorus load did not account for the influence of such a major ecosystem disruptor as the zebra mussel. Eastern basin open water phosphorus concentrations are now even less than the 10 µg/l target value, dramatically reducing the productivity of that basin. Yet, some of the nearshore areas have phosphorus concentrations high enough to support extensive *Cladophora* growth. Attempting to manage the lake system now by simply increasing or decreasing phosphorus loads is no longer workable. Until more is understood about the internal dynamics of phosphorus cycling in the lake, the Lake Erie LaMP has taken the position to continue to support implementation of phosphorus management programs to maintain the phosphorus targets established under the GLWQA.

Changes in land use, development, and the construction of various shore structures have significantly altered the original habitat available along the Lake Erie shoreline. Many of the wetlands have been drained, filled or altered so they no longer function naturally. Shore structures associated with development or built to protect shore property from high water levels have inhibited the natural flow of beach building materials along the shoreline, and, consequently, the natural habitat.

The potential impact of endocrine disruptors on the aquatic community and human health is another issue of concern raised in the 1990s. Weight of evidence suggests that known endocrine disruptor contaminants, such as PCBs, may be impairing Lake Erie populations, both aquatic and human, but it is difficult to make the cause and effect connections.

Issues of concern in Lake Erie will continue to fluctuate over time. Most recently, the area of anoxia in the central basin has expanded, even with the lower phosphorus concentrations in the lake. A number of research projects are ongoing to investigate the cause and the potential impacts.

Current surveillance and monitoring information and recent research must be available to make the appropriate management decisions to address new issues as they arise. Management decisions and actions should take into consideration the potential impact on the overall ecosystem. Using the structure provided by the Lake Erie LaMP process, future remedial and management actions concerning the lake will take into account the expertise, goals and combined resources of the interested public, the private sector, researchers and all the agencies with some jurisdiction over the lake.

2.2 LaMP Structure and Process

Under the Great Lakes Water Quality Agreement (GLWQA) of 1978, as amended by Protocol in 1987, the United States and Canada (the Parties) agreed, "...to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem."

To achieve this goal, the Parties agreed to develop and implement Lakewide Management Plans (LaMPs) for each lake, in consultation with state and provincial governments. The 14 beneficial use impairments listed in Annex 2 of the GLWQA (Table 2.1) are a main focus of LaMPs.

The GLWQA calls for LaMPs specifically to address persistent bioaccumulative toxic substances, particularly those that are causing or likely to cause beneficial use impairments. Ecosystem objectives specific to each lake are to be established to guide LaMP efforts toward defined endpoints. Based on achieving these ecosystem objectives, the LaMPs provide a binational structure for addressing environmental and natural resource issues, coordinating research, pooling resources and making joint commitments to improve the environmental quality of the lakes.

In 1993, a temporary binational Implementation Committee was formed, consisting of members of all the state, federal and provincial agencies with jurisdiction over Lake Erie. The charge to this group was to create a framework upon which to build the Lake Erie LaMP.

Table 2.1: IJC Listing Criteria for Establishing Impairment (IJC, 1989)

Beneficial Use Impairment	IJC Listing Criteria
Restrictions on Fish and Wildlife Consumption	When contaminant levels in fish or wildlife populations exceed current standards, objectives or guidelines, or public health advisories are in effect for human consumption of fish and wildlife.
Tainting of Fish and Wildlife Flavor	When ambient water quality standards, objectives, or guidelines for the anthropogenic substance(s) known to cause tainting are being exceeded or survey results have identified tainting of fish and wildlife flavor.
Degraded Fish and Wildlife Populations	When fish or wildlife management programs have identified degraded fish or wildlife populations. In addition, this use will be considered impaired when relevant, field validated, fish and wildlife bioassays with appropriate quality assurance/quality controls confirm significant toxicity from water column or sediment contaminants.
Fish Tumors and Other Deformities	When the incidence rates of fish tumors or other deformities exceed rates at un-impacted control sites or when survey data confirm the presence of neoplastic or pre-neoplastic liver tumors in bullheads or suckers.
Bird and Animal Deformities or Reproductive Problems	When wildlife survey data confirm the presence of deformities (e.g. cross-bill syndrome) or other reproductive problems (e.g. eggshell thinning) in sentinel wildlife species.
Degradation of Benthos	When the benthic macroinvertebrate community structure significantly diverges from un-impacted control sites of comparable physical and chemical characteristics. In addition, this use will be considered impaired when toxicity (as defined by relevant, field validated bioassays with appropriate quality assurance/quality controls) of sediment associated contaminants at a site is significantly higher than controls.
Restrictions on Dredging Activities	When contaminants in sediments exceed standards, criteria, or guidelines such that there are restrictions on dredging or disposal activities.
Eutrophication or Undesirable Algae	When there are persistent water quality problems (e.g. dissolved oxygen depletion of bottom waters, nuisance algal blooms or accumulation, decreased water clarity, etc.) attributed to cultural eutrophication.
Restrictions on Drinking Water Consumption or Taste and Odor Problems	When treated drinking water supplies are impacted to the extent that: 1) Density of disease-causing organisms or concentrations of hazardous or toxic chemicals or radioactive substances exceed human health standards, objectives or guidelines; 2) Taste and odor problems are present; or 3) Treatment needed to make raw water suitable for drinking is beyond the standard treatment used in comparable portions of the Great Lakes which are not degraded (i.e. settling, coagulation, disinfection).
Recreational Water Quality Impairments	When waters, which are commonly used for total-body contact or partial-body contact recreation, exceed standards, objectives, or guidelines for such use.
Degradation of Aesthetics	When any substance in water produces a persistent objectionable deposit, unnatural color or turbidity, or unnatural odor (e.g. oil slick, surface scum).
Added Costs to Agriculture or Industry	When there are additional costs required to treat the water prior to use for agricultural purposes (i.e. including, but not limited to, livestock watering, irrigation and crop spraying) or industrial purposes (i.e. intended for commercial or industrial applications and noncontact food processing).
Degradation of Phyto/ Zooplankton Populations	When phytoplankton or zooplankton community structure significantly diverges from un-impacted control sites of comparable physical and chemical characteristics. In addition, this use will be considered impaired when relevant, field-validated, phytoplankton or zooplankton bioassays (e.g. <i>Ceriodaphnia</i> ; algal fractionation bioassays) with appropriate quality assurance quality controls confirm toxicity in ambient waters.
Loss of Fish and Wildlife Habitat	When fish or wildlife management goals have not been met as a result of loss of fish or wildlife habitat due to a perturbation in the physical, chemical or biological integrity of the Boundary Waters, including wetlands.

This committee produced the Lake Erie LaMP Concept Paper (U.S. EPA 1995). In addition to addressing critical pollutants, the Implementation Committee felt the integrity of the Lake Erie ecosystem would not be fully protected or restored unless other factors such as habitat loss, nutrient and sediment loading, and non-native invasive species were addressed as well. Therefore, they recommended the scope of the LaMP be broadened to include these other environmental stressors. This decision directed the agencies to embody a stronger overall ecosystem approach in the development of the LaMP. In 1995, binational committees were established to begin actively working on the development of the Lake Erie LaMP. A Status Report was completed in 1999 (U.S. EPA and Environment Canada 1999).

In order to explain clearly the geographic scope of the Lake Erie LaMP, three aspects need to be defined. First, beneficial use impairments were assessed within the waters of Lake Erie, including: the open waters, nearshore areas, and river mouth/lake effect areas. Second, the search for the sources or causes of impairments to beneficial uses is being conducted in the lake itself, the Lake Erie watershed, and even beyond the Great Lakes basin. Third, management actions needed to restore and protect Lake Erie may need to be defined and implemented outside of the Lake Erie basin.

Environment Canada and the U.S. Environmental Protection Agency are the federal co-leads for the Lake Erie LaMP. Other agencies involved in the process include:

Canada

- Agriculture and Agri-food Canada (invited)
- Department of Fisheries and Oceans
- FOCALerie (Federation of Conservation Authorities of Lake Erie)
- Health Canada
- Ontario Ministry of Agriculture and Food
- Ontario Ministry of the Environment
- Ontario Ministry of Natural Resources

United States

- Agency for Toxic Substances and Disease Registry
- Michigan Department of Environmental Quality
- Michigan Department of Natural Resources
- Natural Resource Conservation Service
- New York State Department of Environmental Conservation
- Ohio Department of Natural Resources
- Ohio Environmental Protection Agency
- Pennsylvania Department of Environmental Protection
- Seneca Nation of Indians (invited)
- US Army Corps of Engineers (invited)
- US Fish and Wildlife Service
- US Geological Survey

Binational Observers

- International Joint Commission
- Great Lakes Fishery Commission

Senior managers from each jurisdiction were invited to participate on the Lake Erie LaMP Management Committee, the group charged with overseeing the development of the Lake Erie LaMP. A number of committees and subcommittees were established to assist the Management Committee in fulfilling its charge. The primary supporting committee under the Management Committee is the Lake Erie Work Group. The Work Group carries out the directives of the Management Committee and oversees the creation and progress of the various subcommittees. The Work Group prepares or oversees all the documents prepared under the LaMP and presents them to the Management Committee for review and approval.

Per the direction of the GLWQA, the Lake Erie Concept Paper proposed significant public involvement be utilized throughout the LaMP process. The Lake Erie Binational

Photo: Lower Thames Valley Conservation Authority



Public Forum was created to provide front line coordination and communication with the interested public, and to initiate additional public activities. The Forum contributed to and reviewed the technical background documents used to prepare the LaMP as well as implemented a number of public outreach and education projects in support of the LaMP. The original organizational structure of the Lake Erie LaMP is presented in Figure 2.3.

As the LaMP moved from development to more of an implementation stage, the LaMP structure changed. The current structure is depicted in Figure 2.4. The LaMP has established a research connection via association with the Lake Erie Millennium Network (LEMN). The LEMN was co-convened by the Great Lakes Institute for Environmental Research at the University of Windsor, U.S. EPA's Large Lakes Research Station, the National Water Research Institute of Environment Canada, and Ohio Sea Grant-F.T. Stone Laboratory of the Ohio State University. The LEMN hosts a biennial conference on the status of Lake Erie and identifies current research needs, and works with the LaMP to organize workshops to address various research needs and data gaps.

In an effort to accelerate the entire Great Lakes LaMP process, the Binational Executive Committee (BEC) issued a resolution in July 1999 that recommended a change from the four-stage LaMP process, described in the GLWQA, to production of a biennial document on LaMP status (Table 2.2). This allows planning and implementation to occur simultaneously rather than sequentially, and puts more emphasis on implementation than on document production and review. Having comparable documents for all of the lakes will help to set priorities and identify the issues that may need to be addressed on a Great Lakes basinwide scale.

Figure 2.3: Original organizational structure of the Lake Erie LaMP

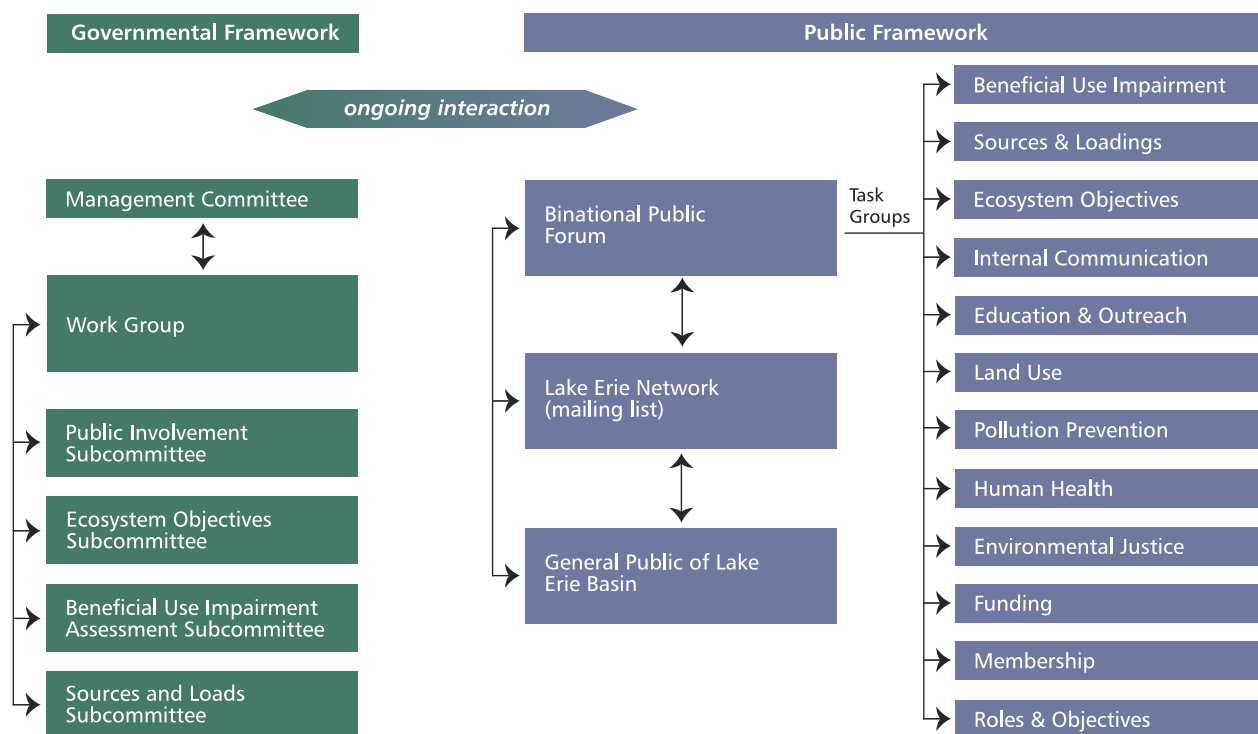


Figure 2.4: Current LaMP organizational structure

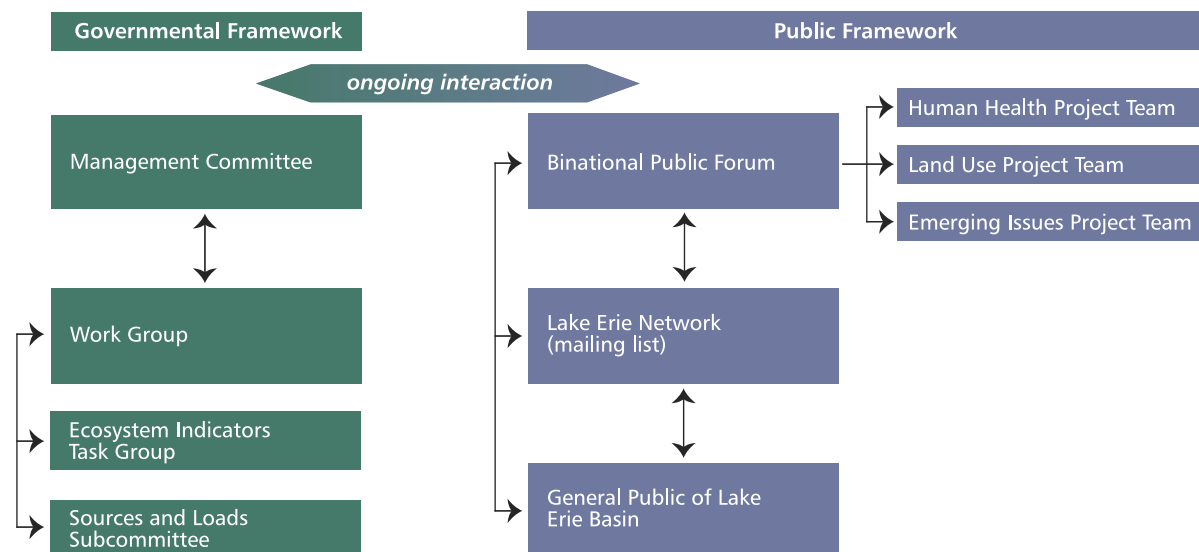


Table 2.2: Binational Executive Committee Consensus Position on the Role of LaMPs in the Great Lakes Restoration Process

The development and implementation of Lakewide Management Plans (LaMPs) are an essential element of the process to restore and maintain the chemical, physical, and biological integrity of the Great Lakes ecosystem. Through the LaMP process, the Parties, with extensive stakeholder involvement, have been defining the problems, finding solutions, and implementing actions on the Great Lakes for almost a decade. The process has taken much longer and has been more resource-intensive than expected.

In the interest of advancing the rehabilitation of the Great Lakes, the Binational Executive Committee calls on the Parties, States, Provinces, Tribes, First Nations, municipal governments, and the involved public to significantly accelerate the LaMP process. By accelerate, we mean an emphasis on taking action and a streamlined LaMP review and approval process. Each LaMP should include appropriate actions for restoration and protection to bring about actual improvement in the Great Lakes ecosystem. Actions should include commitments by the governments, parties and regulatory programs, as well as suggested and voluntary actions that could be taken by non-governmental partners. BEC endorses the April 2000 date for the publication of “LaMP 2000,” with updates every two years.

BEC is committed to ensuring a timely review process and will be vigilant in its oversight.

The BEC respects and supports the role of each Lake Management Committee in determining the actions that can be achieved under each LaMP. BEC expects each Management Committee to reach consensus on those implementation and future actions. Where differences cannot be resolved, BEC is committed to facilitating a decision. BEC recognizes the Four-Party Agreement for Lake Ontario and the uniqueness of the agreed upon binational workplan.

The LaMPs should treat problem identification, selection of remedial and regulatory measures, and implementation as a concurrent, integrated process rather than a sequential one. The LaMPs should embody an ecosystem approach, recognizing the interconnectedness of critical pollutants and the ecosystem. BEC endorses application of the concept of adaptive management to the LaMP process. By that, we adapt an iterative process with periodic refining of the LaMPs which build upon the lessons, successes, information, and public input generated pursuant to previous versions. LaMPs will adjust over time to address the most pertinent issues facing the Lake ecosystems. Each LaMP should be based on the current body of knowledge and should clearly state what we can do based on current data and information. The LaMPs should identify gaps that still exist with respect to research and information and actions to close those gaps.

Adopted by BEC on July 22, 1999.

2.3 References

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Section 3: Vision, Ecosystem Management Objectives, and Indicators



Section 3:
Vision, Ecosystem
Management
Objectives, and
Indicators

3.1 Introduction

1

The Lake Erie LaMP has adopted a generalized ecosystem approach, as outlined in the 1987 amendments to the Great Lakes Water Quality Agreement (GLWQA). This approach recognizes that all components of the ecosystem are interdependent, including the water, biota, surrounding watershed and atmosphere. Humans are considered an integral part of the system. The GLWQA calls for the development of ecosystem objectives and indicators for all the Great Lakes. These would be used to facilitate effective management and co-ordination within and between agencies working in the Lake Erie watershed. There are three steps involved in setting a direction for the Lake Erie ecosystem: 1) a preferred ecosystem management alternative must be selected; 2) ecosystem vision and management objectives must be developed that describe in narrative form more details to set the stage for the actions needed to achieve the preferred alternative; and 3) indicators must be developed to measure progress in achieving the desired ecosystem alternative.

3.2 Selection of a Lake Erie Ecosystem Management Alternative

Ecosystem Alternative Development Process

For Lake Erie, the level of change in the ecosystem has been extensive, and in many cases appears irreversible (Burns 1985). We cannot return to the pre-settlement conditions of the 1700s, but we can work toward achieving a healthier, more diverse and less contaminated ecosystem.

The Lake Erie LaMP Ecosystem Objectives Subcommittee (EOSC) was charged with the task of developing ecosystem management objectives for Lake Erie. The EOSC is a binational group of about 15 individuals with expertise in limnology, water quality, and fisheries and wildlife management. Three members of the Lake Erie Binational Public Forum worked closely with the committee throughout the exercise. The first step in the process was to identify ecosystem management alternatives. The committee began the exercise by holding four public workshops around the basin to gain ideas on the desired

state of the Lake Erie ecosystem. This was followed by an expert workshop where published information and expert opinion were solicited concerning key relationships in the ecosystem.

A conceptual model of three ecosystem alternatives was developed for initial discussion. Several other attempts were made at developing a model that could be used for Lake Erie. As a result, a fuzzy cognitive map (FCM) approach was adopted to model ecosystem alternatives for Lake Erie. A FCM model is one way to analyze a complex system by representing the most important components of the system as nodes of a network. A change at one node will affect all connected nodes, and then all the nodes connected to those nodes, generating a ripple effect. Taking an FCM approach required more data and, therefore, a second expert workshop was held. The results of the second workshop led to the development of an FCM model for the lake dubbed the Lake Erie Systems Model. The model is being used as a tool to help understand how various components of the ecosystem interact, but it is not a panacea to predict future conditions.

Three major categories of actions and reactions are used to explain the output of the Lake Erie Systems Model: 1) management levers; 2) ecosystem health response; and 3) beneficial use to humans. Management levers are a variety of human actions that affect the ecosystem. Ecosystem health response describes the condition of individual biotic and habitat components and the reaction to the management levers. Beneficial uses refer to those uses defined in the GLWQA

that are affected by the management levers. By randomly and simultaneously moving all management levers in different directions and monitoring responses of all non-lever variables, a large set of different potential outcomes in the ecosystem can be generated. These outcomes can then be grouped into a form that can be recognized and described using a statistical clustering procedure. Groups that are considered to be significantly different from each other constitute ecosystem alternatives. A detailed description of how the model was developed and how it processes data can be found in the ecosystem objectives subcommittee's report, Colavecchia et al. (2000).

The model generated various ecosystem alternatives. These alternatives do not include social, economic, or political values because they are not part of the natural ecosystem. Rather, these values were used to determine the ecosystem alternative that was chosen.

Model Results

Of the management levers examined in the model, those that affected the availability of natural, undisturbed land caused the largest response across the greatest number of variables. Therefore, the availability of natural lands was the key driver of the ecosystem clusters. Nutrient levels were the second most important influence but did not have the impact that natural land (habitat) had on the ecosystem. In other words, phosphorus can be strictly managed, but unless natural land or habitat is protected and restored, only marginal response will be seen by many components of the ecosystem. It was determined that changes in land use that represent a return towards more natural landforms or that mitigate the impacts of urban, industrial and agricultural land use, are the most significant actions that can be taken to restore the Lake Erie ecosystem.

The ecosystem alternatives derived from the model were described based on their gain in natural land compared to the status quo conditions of the 1990s. From the modeling exercise, seven distinct ecosystem management alternatives emerged. Three alternatives represented highly degraded environmental conditions relative to 1990 conditions and were discarded as not viable alternatives for a future state of Lake Erie. The remaining four alternatives (Table 3.1) represented existing or improved environmental conditions. Alternative 3 represents moderate loss of natural landforms relative to status quo (Alternative



Photo: Michelle Fletcher

Table 3.1: Summary of Ecosystem Alternatives for Lake Erie

Management Lever or effect	Action or effect	Ecosystem Alternatives			
		1	2	3	4
Agricultural Land Use	Mitigation of impact	very strong	strong	strong	status quo
Industrial Land Use	Mitigation of impact	very strong	moderate	moderate	status quo
Urban Land Use	Mitigation of impact	very strong	strong	moderate	status quo
Natural Landscapes	Restoration	small gain	small gain	moderate loss	status quo
Phosphorus Concentration	Reduced concentrations in tributaries, nearshore and lake	very strong	strong	strong	status quo
Phosphorus from Land (non-point source)	Reduction in loadings	very strong	very strong	very strong	status quo
Phosphorus from STPs	Reduction in loadings	very strong	moderate	strong	status quo
Total Suspended Solids	Reduction in concentration	very strong	very strong	very strong	status quo

4), while Alternatives 1 and 2 represent small improvements in the amount of natural landscapes in the basin. Alternatives 3, 2, and 1 represent increasingly more progressive mitigation of agricultural, industrial and urban land uses. The mitigation results in very strong reductions in nutrient export from land and total suspended solids concentrations. The alternatives differ in the level of reduction of phosphorus exports from sewage treatment plants (STPs) with Alternative 2 requiring moderate reduction, Alternative 3 a strong reduction and Alternative 1 a very strong reduction.

The selection of an ecosystem alternative toward which to manage Lake Erie is not a trivial issue. There are many competing and incompatible uses of Lake Erie, and multiple agencies (federal, state and local) have jurisdiction over one or more components of the ecosystem. Societal factors that influence the choice include economics, social justice, land use, and others. To be an effective tool, the LaMP, including the desired ecological state for Lake Erie, must have the support and commitment of the various environmental managers, decision makers and the public. Without a consensus on ecological conditions to be achieved, multiple management efforts could easily be competing, ineffective, and/or counterproductive. Ultimately, the process for choosing an ecosystem alternative for management purposes becomes one of identifying which one is most closely compatible with societal values of the residents in the basin.

The Lake Erie LaMP Work Group considered several options for soliciting opinions and comments on preferred ecosystem alternatives from the governing agencies, environmental groups, industry and the general public. Opinions were solicited through informal discussions, Lake Erie Binational Public Forum input, and agency reviews. In June 2000, the LaMP Work Group reached consensus that Ecosystem Alternative 2 would represent the preferred ecosystem of the Work Group. In September 2001, the LaMP Management Committee endorsed this conclusion. Additional discussions with stakeholders, including the public, concluded with the selection of Ecosystem Alternative 2.

Ecosystem Alternative 2 is consistent with the themes of sustainable development and of multiple benefits to society of a healthy Lake Erie ecosystem. The analysis supporting Ecosystem Alternative 2 highlights the importance and urgency of improving land use activities, continued diligence in nutrient management, and the vulnerability of fish and wildlife species to human activities.

3.3 Developing a Lake Erie Vision and Ecosystem Management Objectives

The second step involved in setting a direction for the Lake Erie ecosystem was the development of a vision and ecosystem management objectives using the selected ecosystem alternative. The vision is a written description of the selected ecosystem alternative. The ecosystem management objectives describe in narrative form more details to set the stage for the actions needed to achieve the Vision.

The Lake Erie LaMP has defined the term integrity, from Karr and Dudley (1981), as “the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitats of the region.”

3.3.1 The Lake Erie Vision

Ecosystem Alternative 2 became the Lake Erie Vision. This vision is consistent with the themes of sustainability and of the multiple benefits to society of a healthy Lake Erie ecosystem. Maintaining healthy ecosystems and restoring degraded ecosystems will foster improved economic and human health through a variety of avenues (maintaining water quality, tourism, recreation, etc.). The Lake Erie Vision is presented below:

Our Vision is a Lake Erie basin ecosystem...

Where all people, recognizing the fundamental links among the health of the ecosystem, their individual actions, and their economic and physical well-being, work to minimize the human impact in the Lake Erie basin and beyond;

Where natural resources are protected from known, preventable threats;

Where native biodiversity and the health and function of natural communities are protected and restored to the greatest extent that is feasible;

Where natural resources are managed to ensure that the integrity of existing communities is maintained or improved;

Where human-modified landscapes provide functions that approximate natural ecosystem processes;

Where land and water are managed such that water flow regimes and the associated amount of materials transported mimic natural cycles; and

Where environmental health continually improves due to virtual elimination of toxic contaminants and remedial actions at formerly degraded and/or contaminated sites.



3.3.2 Developing Ecosystem Management Objectives and Rationale

Ecosystem management objectives are targets that, when all are achieved, should result in the attainment of the Vision for the Lake Erie ecosystem.

As outlined above, the Lake Erie Vision was selected after extensive review and input. However, the vision does not prescribe the necessary management goals to realize the desired ecosystem vision. Management goals are dependent on the ecosystem management objectives, formulated to be consistent with the vision, and are based on the present state of the ecosystem components. Input from the Lake Erie community on the preferred ecosystem alternative helped define the degree of implementation that will be necessary and acceptable to be consistent with the vision.

The Lake Erie ecosystem has three very distinct basins, and within the entire watershed of the lake there are 34 third-order sub-watersheds, many of which have unique features and pressures. The impact of non-native invasive species in the Lake Erie ecosystem contributes to instability, and new species continue to enter, thereby compounding the problem. Implementation of the management strategies moves the ecosystem in the right direction, and leads to improvements in biological integrity. The process is iterative. Tracking of recovery in relation to management interventions leads to projections of reasonable and feasible endpoints for biological integrity at appropriate units of the ecosystem (i.e. watersheds and areas of influence in the lake, bays, basins).

The overall proposed ecosystem management objectives are presented as principles for management actions to achieve the Lake Erie ecosystem vision. The ecosystem management objectives are presented in relation to the main management categories influencing the status of the lake: land use; nutrients; natural resource use and disturbance; chemical and biological contaminants; and non-native invasive species. In proposing these ecosystem management objectives, it is recognized that each watershed and basin may require varying degrees of implementation. The *status quo* or “current conditions” are generally reflective of conditions found in the mid-to-late 1990s.

3.3.3 Ecosystem Management Objectives and Rationale

Land Use

Strategic Objective:

Land-based activities enhance native biodiversity and ecosystem integrity.

Tactical Objective:

Land use activities result in gains in the quantity and quality of natural habitat in order to support the maximum amount of native biodiversity and community integrity that can be achieved and be sustained for the benefit of future generations.

Rationale:

Ecosystem alternative analysis identified land use practices as the dominant management category affecting the Lake Erie ecosystem. Poor land use management has resulted in increased water runoff containing sediments, nutrients, and chemicals to Lake Erie, and reduced areas of natural landscapes and habitats. Key elements within the land use management category are gains in quality natural lands and environmentally sound management practices for rural, urban and industrial landscapes.

Best management practices (BMPs) can mitigate many deleterious land uses and their impacts to the extent that natural habitat (ecosystem) quality and quantity can improve. It is expected that there will be increasing demands and pressures for land conversion in the Lake Erie basin. Proactive planning for these pressures needs to include the protection of critical habitat corridors that connect and link habitats between the lake, the wetlands and the upland habitat. Specific targets need to be established, which include securing, protecting and restoring natural lands. A watershed approach is critical to developing local solutions and to maximize gains with partners.

Nutrients

Strategic Objective:

Nutrient levels are consistent with ecosystem goals (watershed and basinwide).

Tactical Objective:

Nutrient inputs from both point and non-point sources are managed to ensure that ambient concentrations are within bounds of sustainable watershed management and consistent with the Lake Erie Vision.

Rationale:

Current nutrient inputs are resulting in reduced use of beaches, changes in aquatic community structure, and increased algal blooms. It is important that all sources that contribute to the watershed nutrient load and ultimately to the basin load, be managed to limit local and regional impacts. Best management practices and point source controls need to be implemented with consideration of the ecological requirements for the maintenance or recovery of healthy aquatic communities in the watershed, the hydrologic cycle and water usage. In addition to phosphorus, other nutrients and their various forms, such as nitrates, also need to be included in assessments of watershed and basinwide impacts.

Natural Resource Use and Disturbance

Strategic Objective:

Ecologically wise and sustainable use of natural resources

Tactical Objective:

Natural resource use (e.g. commercial and sport fishing, hunting, trapping, logging, water withdrawal) and disturbance by human presence or activity be managed to ensure that the integrity of existing healthy ecological communities be maintained and/or improved, and provide benefits to consumers.

Rationale:

Commercial and sport fishing, hunting, trapping, logging, water withdrawal and disturbance by human presence or activity may have negative impacts on target species, habitats and more broadly on other components of the ecosystem if not properly managed. Natural resource use (exploitation and disturbance) should be managed in such a manner as to encourage the recovery of degraded communities. The harvest of valued fish, timber resources, extraction of aggregate deposits, the removal of water, and the utilization of other features of the working landscape should be done in a manner that is sustainable and which affords the greatest opportunity to preserve and enhance the biological integrity of the Lake Erie ecosystem. Integrity is a general term for the recurring structure and composition of a community over time, due to internal regulation.

Sustainable management of natural resources can realize valued harvests for present and future generations and still maintain essential habitat function. Resource extraction is recognized as valued economic activity but should be done in a manner to prevent or mitigate to the greatest extent possible the negative environmental impacts.



Photo: U.S. EPA Great Lakes National Program Office

Chemical and Biological Contaminants

Strategic Objective:

Virtual elimination of toxic chemicals and biological contaminants.

Tactical Objective:

Toxic chemical and biological contaminant concentrations within the basin must be virtually eliminated.

Rationale:

Biological contaminants are defined here as pathogens, toxins released by cyanobacteria (such as microcystin from *Microcystis*) or bacteria. Toxic chemicals and biological contaminants degrade watersheds, not only impacting local fauna, but potentially having lakewide impacts. Locally contaminated areas may affect populations of fish and wildlife in the open waters of the lake if those locations are used for feeding, spawning or nursery habitat. The amount of toxic contaminants in the Lake Erie ecosystem is the result of the combined inputs from point and non-point sources within the basin, upstream loadings transported via the Detroit River, and long-range atmospheric transport from regional and global sources. Effective management of local point and non-point sources and adopting pollution prevention practices can improve, and have improved, watershed and basin ecosystem quality. However, broad based actions such as those promoted in the Great Lakes Binational Toxics Strategy, the Stockholm Convention on Persistent Organic Pollutants (POPs), and the United Nations Agenda 21 that address global atmospheric pollutant transport, are also required to fully reach this objective since these programs address regional and global atmospheric pollutant transport.

Non-native Invasive Species

Strategic Objective:

Prevent further invasions of non-native invasive species. Control existing invasive non-native species where possible.

Tactical Objective:

Non-native invasive species should be prevented from colonizing the Lake Erie ecosystem. Existing non-native invasive species should be controlled and reduced where feasible and consistent with other objectives.

Rationale:

Successful invaders may prey upon native species or compete with them for limited resources, altering the structure of the local and lakewide ecosystems. The presence of non-native invasive species is the result of intentional or unintentional introductions, or range expansion and colonization. The LaMP has identified invasive non-native species as one of the key problems impairing the Lake Erie ecosystem. The impact of non-native invasive species needs to be minimized where feasible by preventing access, and by controlling or managing them once they have entered the ecosystem.

3.4 Linking the Vision and Ecosystem Management Objectives to Beneficial Use Impairments

Restoring impaired beneficial uses to the Lake Erie watershed is a driving force behind the development of the Lake Erie LaMP. Therefore, as the LaMP developed its vision and ecosystem management objectives the relationship between these and the identified beneficial use impairments (BUIs) were defined (Colavecchia et al. 2000).

The underlying causes of the BUIs, as identified by the Beneficial Use Impairment Assessment process, are complicated. Their restoration will frequently be linked to more than one ecosystem management objective. Successful achievement of the Lake Erie LaMP vision and ecosystem management objectives will realize the restoration of beneficial use impairments. These relationships are summarized in Table 3.2.

Table 3.2: Linking Ecosystem Management Objectives to Lake Erie's Beneficial Use Impairments
(Colavecchia *et al.* 2000)

Ecosystem Management Objective	Beneficial Use Impairment
Land Use	Degraded Fish and Wildlife Populations Restrictions on Fish and Wildlife Consumption Bird or Animal Deformities or Reproductive Problems Restrictions on Dredging Degradation of Benthos Eutrophication or Undesirable Algae Beach Closings Loss of Fish and Wildlife Habitat
Nutrients	Degraded Fish and Wildlife Populations Degradation of Benthos Eutrophication or Undesirable Algae Degradation of Aesthetics Degradation of Phytoplankton and Zooplankton Populations
Chemical and Biological Contaminants	Restrictions on Fish and Wildlife Consumption Bird or Animal Deformities or Reproductive Problems Fish Tumors and Other Deformities Degraded Fish and Wildlife Populations Restrictions on Dredging Activities (quality) Beach Closings Degradation of Benthos
Natural Resource Use and Disturbance	Degraded Fish and Wildlife Populations Loss of Fish and Wildlife Habitat
Non-native Invasive Species	Degraded Fish and Wildlife Populations Degradation of Benthos Degradation of Aesthetics Loss of Fish and Wildlife Habitat Eutrophication or Undesirable Algae Degradation of Phytoplankton and Zooplankton Populations

3.5 Developing Lake Erie Indicators

Ecosystem indicators and corresponding monitoring programs allow us to evaluate progress in achieving the ecosystem management objectives and the Lake Erie LaMP vision. There are many challenges associated with establishing a suite of indicators for Lake Erie because of its many unique characteristics (e.g., three distinct basins, high biodiversity, heavily populated and developed land base, vulnerability to non-native species invasions).

An Indicators Task Group was appointed by the Lake Erie LaMP Work Group and tasked with developing a suite of indicators that will allow progress toward achieving the ecosystem management objectives to be tracked. The approach being taken is to: (a) compile a list of potential indicators representative of a variety of ecosystem components; (b) complete a review of the proposed indicators; (c) get scientific consensus for the use of these indicators, and (d) present a recommended suite of indicators to the Lake Erie LaMP.

3.5.1 Purpose and Criteria for Selection

Ecosystem indicators have been identified by SOLEC (Bertram and Stadler-Salt, 1998) as measurable features that provide managerially and scientifically useful evidence of environmental and ecosystem quality, or reliable evidence of trends in quality. For Lake Erie, this definition of indicators must be broadened in order to link them to the Lake Erie Ecosystem Management Objectives. Therefore, the Lake Erie LaMP definition of an indicator is:

A measurable feature that identifies the current state of the ecosystem relative to the desired state of the ecosystem, as described by the Lake Erie Vision and Ecosystem Management Objectives.

The purpose of the Lake Erie LaMP indicator suite is to: (1) assess overall ecosystem management integrity; (2) evaluate components contributing to change at component level and basin level; (3) evaluate important components for reporting and long-term trends; and (4) provide predictive capacity (i.e., allow us to anticipate problems and adopt a proactive approach).

Numerous indicators have already been developed or are being developed to address different purposes in the Great Lakes basin and beyond. In order to ensure that the selected indicators meet the purposes of the Lake Erie LaMP, a set of selection criteria was developed. Each potential indicator will be evaluated using the selection criteria.

3.5.2 Developing Recommended Indicators

The Indicators Task Group began accumulating potential indicators using a questionnaire that was distributed to the scientific and management community in June 2004. The questionnaire requested information on indicators that were currently in use or in development, with the intent that, wherever possible, the LaMP indicator suite would build upon work that has already been done.

An indicator matrix was developed as a means of organizing and understanding the application of the proposed indicators (Table 3.3). The matrix structure is based on the five habitat zones developed by the Lake Erie Millennium Network: terrestrial, streams, coastal wetlands, nearshore, and offshore. For each indicator category, indicators will

Table 3.3: The Lake Erie Indicators Matrix

Indicator Category	Habitat Zone				
	Terrestrial	Streams	Coastal Wetlands	Nearshore	Offshore
PRESSURE INDICATORS					
<i>Management Objectives:</i>					
Natural Lands					
Nutrients					
Chemical Contamination					
Biological Contamination					
Non-Native Invasive Species					
Resource Use and Disturbance					
<i>Processes:</i>					
Flow Disruption					
Energy Disruption					
Economic Disruption					
STATE INDICATORS					
Plant Cover					
Food Web Base					
Lower Food Web (benthic invertebrates)					
Lower Food Web (plankton)					
Middle Food Web (fish)					
Upper Food Web (fish)					
Upper Food Web (amphibians/reptiles/birds)					

be developed within each habitat zone. The matrix is divided into two general indicator categories utilized by SOLEC: pressure and state (Bertram and Stadler-Salt, 1998). The Pressure Indicator category is further sub-divided into Management Objectives indicators (used to measure progress toward the Lake Erie ecosystem management objectives) and Processes indicators (used to measure impacts to important ecosystem and economic processes). The State Indicators will be used to measure the current state of the various components of the Lake Erie ecosystem.

The six management objectives indicator categories – natural lands, nutrients, chemical contamination, biological contamination, resource use and disturbance and non-native invasive species – correspond directly to the LaMP ecosystem management objectives and will be used to report on the LaMP's progress in achieving the Lake Erie Vision.

The processes and state indicators provide a further level of detail that will allow the LaMP to go beyond reporting progress on achieving the vision, and will allow an evaluation of ecosystem components that are contributing to change, an evaluation of important components for reporting and long-term trends, and will provide predictive capacity.

3.5.3 Review of the Candidate Indicators

Each of the cells within the Lake Erie indicators matrix has been populated with candidate indicators that had been proposed by respondents of the questionnaire or during discussions of the Indicators Task Group. This “comprehensive matrix” includes all possible indicators, whether they are already in use elsewhere, currently in development or still need to be developed.

The next step is to refine the list of candidate indicators based on their feasibility specifically for use by the Lake Erie LaMP.

3.6 References

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Photo: Grand River Conservation Authority

Section 4: Synthesis of Beneficial Use Impairment Assessment Conclusions



4.1 Introduction

Scope

Annex 2 of the Great Lakes Water Quality Agreement requires that each LaMP assess impairment to 14 beneficial water resource uses as the first step in identifying restoration and protection actions for each of the Great Lakes. The 14 beneficial use impairments and the criteria for determining impairment are outlined in Table 2.1. The Lake Erie LaMP also recognizes that more than just these 14 beneficial use impairments will need to be addressed before Lake Erie can be fully restored. These other issues, or stressors, are discussed in other sections of the LaMP document.

Experts in each respective impairment area completed beneficial use impairment assessments over several years (Table 4.1). The geographic scope of the impairment assessment includes the open waters of Lake Erie, nearshore areas, embayments, river mouths and the lake effect zones of all Lake Erie tributaries. The location of the cause or source of the impairment does not have to fall within the above-mentioned geographic boundaries to be considered within the LaMP evaluation process. **When an impaired beneficial use is identified in a particular basin in the summary tables throughout this section, it means that impairment is occurring somewhere in that basin, not necessarily throughout the entire basin referenced.**

Table 4.1: Summary of Lake Erie LaMP Beneficial Use Impairment Assessment Reports Completed

Use Impairment	Impairment Conclusion	Assessment Completed	Authors
Fish & Wildlife Consumption Restrictions	Impaired	1998	Lauren Lambert, Ohio EPA
Tainting of Fish & Wildlife Flavor	Not Impaired	1997	Lauren Lambert, Ohio EPA
Degradation of Fish Populations	Impaired	1999	Roger Knight, Ohio DNR and Phil Ryan, Ontario MNR
Degradation of Wildlife Populations and Loss of Wildlife Habitat	Impaired	2001	Lauren Lambert, Ohio EPA; Jeff Robinson, Canadian Wildlife Service; Mark Shieldcastle, Ohio DNR; Madeline Austin, Environment Canada
Fish Tumors or Other Deformities	Impaired	2000	Paul Baumann, USGS; Victor Cairns, Fisheries and Oceans Canada; Bill Kurey, US Fish and Wildlife Service; Lauren Lambert and Roger Thoma, Ohio EPA; Ian Smith, Ontario MOE
Animal Deformities or Reproduction Problems	Impaired	2000	Keith Grasman, Wright State University; Christine Bishop, Canadian Wildlife Service; William Bowerman, Clemson University; James Ludwig, SERE Group; Pamela Martin, Canadian Wildlife Service; Lauren Lambert, Ohio EPA
Degradation of Benthos	Impaired	2001	Jan Ciborowski, University of Windsor
Restrictions on Dredging Activities	Impaired	1997	Julie Letterhos and Kurt Kohler, Ohio EPA
Eutrophication or Undesirable Algae	Impaired	1999	Serge L'Italien, Murray Charleton and Mike Zarull, Environment Canada; Todd Howell, Ontario MOE; Paul Bertram, USEPA-GLNPO; Roger Thoma, Ohio EPA
Restrictions on Drinking Water Consumption or Taste & Odor Problems	Not Impaired	1997	Lisa Thorstenberg, U.S. EPA and Serge L'Italien, Environment Canada
Recreational Water Quality Impairments	Impaired	1999	Beth Kwavnick, Health Canada; and Joyce Mortimer, Health Canada
Degradation of Aesthetics	Impaired	1997	Lauren Lambert, Ohio EPA
Added Costs to Agriculture or Industry	Not Impaired	2000	Lauren Lambert, Ohio EPA
Degradation of Phytoplankton & Zooplankton Populations	Impaired	1998	Ora Johannsson, Fisheries and Oceans Canada and Scott Millard, Environment Canada
Loss of Fish Habitat	Impaired	1998	Larry Halyk, Ontario MNR and David Davies, Ohio DNR

The Ecosystem Approach in Action - Step 1

For the Lake Erie LaMP, the term ecosystem approach means: a) remediating both contaminant and noncontaminant causes of impairment is important to the restoration of Lake Erie, and b) management actions must consider impacts to all key components of the Lake Erie ecosystem before they are implemented.

In keeping with item “a”, this beneficial use impairment assessment treats all impairments and known causes equally, regardless of the type, severity, duration, trend, geographic extent, or magnitude. The primary causes of impairment are chemical contaminants, habitat loss and degradation, exotic species, and the associated impacts to energy and contaminant flow in the food web. Remediation of any one of these causes without addressing the others will not fully restore Lake Erie.

In terms of item “b”, existing objectives such as those in the North American Waterfowl Management Plan (NAWMP), the National Shorebird Plan, Partners in Flight and the Lake Erie Fish Community Goals and Objectives (FCGO) were used to complete the beneficial use impairment assessment. Some of these existing objectives were developed with primarily one group of organisms in mind, and not necessarily the entire ecological community. In the case of wildlife, most of the objectives are not Lake Erie specific. It is important to use and fine tune existing objectives with new proposed objectives to prevent conflicting management actions. An example of such a conflict is diking wetlands to protect wildlife habitat from destruction by lake wave action, but consequently isolating the wetland from use as a spawning and nursery area for lake fish.

The Lake Erie LaMP has developed a vision and ecosystem management objectives, described in Section 3 of this document, that will allow us to explore the effects of changes in management strategies on all parts of the ecosystem. These ecosystem management objectives set the stage to prioritize actions that must be implemented to restore beneficial uses.

Synthesis Approach

It is recognized that many improvements already have occurred in the Lake Erie environment. This section of the document summarizes the problems that still exist and that the LaMP must address. The impairment conclusions for each of the Lake Erie assessments are summarized in tables within each subsection and serve as the preliminary problem definition for the lake. Eleven of the assessments concluded that impairment is occurring somewhere within the geographic scope of the Lake Erie LaMP.

In general, more impairments are identified in the western basin and in the lake effect zones of tributaries than in the other two basins. However, this fact must be interpreted carefully. While it is known that contaminant impacts are generally greatest in the western basin, there are several other key considerations. The range of certain sensitive species is limited to the western basin and acreage of certain habitat types was historically greatest in the western basin. For example, in terms of impacts to coastal wetlands, the former Black Swamp alone covered nearly 300,000 acres before land use changes reduced the remaining acreage to the current 30,000 acres. In other cases most of the data were collected from the western basin. Because the states and province are responsible for regulating surface waters in their respective jurisdictions, an abundance of tributary data is available. Seven of the 12 Lake Erie basin AOCs are located in the western basin or watershed and have already completed extensive beneficial use impairment assessments for those specific geographic areas. And finally, certain impairments are limited to tributaries and nearshore areas by default (e.g. beach impairments, restrictions on dredging activities and many of the habitat impairments).

The purpose of this section is to briefly synthesize the assessments by linking the impairment conclusions, causes, and trends among impairments. Impairment assessment conclusions have been grouped into three broad categories based on the primary areas of public interest to date: human use impairments (section 4.2), impairments due to chemical contaminants (section 4.3), and ecological impairments (section 4.4), with a synthesis narrative for each. All the original beneficial use assessments were completed between 1997 and 2001. Some updates as of 2004 are added, but no impairment assessment conclusions have changed. As the ecosystem of Lake Erie changes over time, periodic re-assessments

of each beneficial use will be needed. **The LaMP hopes to have all beneficial use impairments re-assessed by 2008. The research needs and data gaps presented in the 2000 report have been removed from this section to be incorporated into a Lake Erie LaMP research and monitoring agenda that is being drafted as part of the 2004-2006 Paths to Achievement (workplan).**

More detailed technical information is available at www.epa.gov/glnpo/lakeerie/buia/index.html.

4.2 Human Use Impairments

The human use assessment results answer the questions, are Lake Erie waters: a) fishable, b) swimmable, c) drinkable, d) navigable, and e) clean enough for routine agricultural and industrial use? The impairment conclusions for each are summarized in Table 4.2 and show that Lake Erie waters are not yet completely fishable, navigable, and swimmable. The major causes of these impairments to human use are chemical contaminants and elevated levels of bacteria in recreational waters.

Table 4.2: Summary of Human Use Impairments (updated 2004)

Impaired Use	Impairment Conclusions by Basin	Causes of Impairment
Fish and Wildlife Consumption Restrictions	<i>FISH</i> - Impaired in all basins. <i>WILDLIFE</i> - Impaired in eastern basin; inconclusive for western and central basins. UPDATE 2004: <i>FISH</i> * - sport fish consumption advisories in open and tributary waters of all basins. <i>WILDLIFE</i> - consumption advisories for snapping turtles in NY and OH and waterfowl in NY.	<i>FISH</i> - PCBs, mercury, lead and dioxins <i>WILDLIFE</i> - PCBs, chlordane, DDT and mirex UPDATE 2004: <i>FISH</i> - no change <i>WILDLIFE</i> - PCBs, chlordane, DDT, mirex, mercury, lead
Tainting of Fish and Wildlife Flavor	Not Impaired UPDATE 2004: no change	None UPDATE 2004: no change
Restrictions on Dredging Activities	Impaired in tributary mouths and harbors of all basins. Confined disposal is required in certain areas. UPDATE 2004: No change	PCBs, heavy metals UPDATE 2004: PCBs, heavy metals, PAHs
Restrictions on Drinking Water Consumption or Taste and Odor Problems	Not Impaired UPDATE 2004: no change	None UPDATE 2004: no change
Recreational Water Quality Impairments	Impaired in nearshore waters of all basins; Inconclusive for offshore waters of all basins. UPDATE 2004: Nearshore areas in all basins. Exceedances of bacterial guidelines established to protect human health.	Exceedances of <i>E. coli</i> and/or fecal coliform guidelines, PAHs ⁺ , PCBs ⁺ UPDATE 2004: Contact advisory for Black River AOC lifted in 2004
Degradation of Aesthetics	Impaired in nearshore waters, all basins; Inconclusive for open waters of the western basin (Table 4.4). UPDATE 2004: High turbidity; obnoxious odors; decaying <i>Cladophora</i> on the shoreline; seasonal fish die-offs of non-native alewife and gizzard shad; hindrances to recreational use due to floating garbage, debris and zebra mussels.	Excessive <i>Cladophora</i> , point/non-point source stormwater runoff, floating garbage and debris, dead fish, excessive zebra mussels on beaches UPDATE 2004: no change
Added Costs to Agriculture and Industry	Not Impaired UPDATE 2004: no change	None UPDATE 2004: no change

*Commercial fishermen in Ontario are prohibited from selling carp that are 32 cm or larger, due to PCBs.

⁺ PAHs are the basis for a human contact advisory in the Black River (OH) AOC and PCBs are the basis for a human contact advisory in the Ottawa River (Maumee AOC). These advisories were issued by the Ohio Department of Health and mean that contact with sediment or water in these areas should be avoided.



4.2.1 Summary of the 1998 Fish Consumption Restrictions Beneficial Use Impairment Assessment

Eating fish is an important part of a well-balanced diet. However, it is important to be aware of restrictions that may be in place for certain species, certain areas and when eating larger fish.

Fish consumption impairments occur when contaminant levels in fish exceed current standards, objectives or guidelines, or public health advisories are in effect for human consumption of fish or wildlife. Impairment to human consumption of Lake Erie fish is occurring. Public health advisories for human consumption of sport fish are in place for many geographic locations within Lake Erie waters.

Particularly noteworthy from the 1998 assessment were “DO NOT EAT” consumption advisories for certain species/size classes of fish in Lake Erie, Maumee and Long Point Bays, the Maumee, Ottawa, Detroit, Raisin and Rouge Rivers, and the Buffalo River/Harbor area. In addition, commercial fishermen in Ontario were prohibited from harvesting carp that are 32 cm or larger, due to PCBs. Since the original assessment, there is also now a “DO NOT EAT” advisory for carp >75cm in Wheatley Harbour, for walleye >65cm in the Detroit

River, and commercial fishermen in Ontario are only permitted to harvest channel catfish 33cm or smaller. The “DO NOT EAT” advisory on the Rouge River was changed to a less restrictive advisory following a PCB-contaminated sediment remediation project.

The presence of contaminants in Lake Erie, which are the basis for these advisories, exceed the Great Lakes Fisheries Commission’s Lake Erie Committee (LEC) draft objective related to fish consumption advisories. The goal of this objective is to “reduce contaminants in all fish species to levels that require **no advisory** for human consumption.” The existence of fish consumption advisories also does not meet the IJC objective of no restrictions on the human consumption of fish in waters of the Great Lakes Basin Ecosystem.

Table 4.3: Summary of Sport Fish Consumption Advisories by Lake Erie Basin

Basin	Sport Fish Consumption Advisory
Western Basin Nearshore	Impaired. Fish advisories for Maumee, Portage, Sandusky, Raisin, Rouge, Detroit, and Ottawa River tributaries, and Wheatley Harbor and Maumee Bay. Update 2004: no change
Western Basin Offshore	Impaired. Fish advisories for Lake Erie waters of all jurisdictions bordering this basin. Update 2004: no change
Central Basin Nearshore	Impaired. Fish advisories for Vermilion, Huron, Black, Cuyahoga, Ashtabula, and Chagrin Rivers, Conneaut Creek tributaries and Rondeau Bay. Update 2004: Add Grand River (OH)
Central Basin Offshore	Impaired. Fish advisories for Lake Erie waters of all jurisdictions bordering this basin. Update 2004: no change
Eastern Basin Nearshore	Impaired. Fish advisories for Presque Isle Bay, Buffalo River/Harbor, Grand River, Ontario, Big Creek, and Long Point Bay. Update 2004: no change
Eastern Basin Offshore	Impaired. Fish advisories for Lake Erie waters of all jurisdictions bordering this basin. Update 2004: no change

Fish consumption advisories are issued to assist sport fish consumers in protecting their health. The goal of advisories is to minimize human exposure to chemical contaminants that are present in fish tissue. The choice of which fish to consume, how frequently to consume, and how to prepare it, remains with the individual. In contrast, commercial fishing restrictions are enforceable standards and are therefore mandatory.

The most common chemical causes of sport fish consumption advisories are PCBs and mercury, although advisories in some areas are issued due to lead and dioxins. Additional chemical parameters that are routinely monitored vary by jurisdiction. Sport fish consumption advisories are educational tools that not only identify geographic locations where fish are affected, but also inform consumers of fish species and size classes likely to contain higher levels of chemical contaminants, offer recommendations on frequency of consumption, and recommend preparation and cooking techniques that reduce risk of exposure to contaminants that accumulate in fatty tissues, such as PCBs. The presence of mercury in fish has been of particular concern because it accumulates in the tissue of fish rather than the fat. Food preparation methods such as trimming fat and skin, and broiling rather than frying do not reduce exposure to mercury. The only effective option to minimize exposure to mercury present in fish tissue is to follow fish consumption advisories and to avoid eating the internal organs of the fish.

As an example of jurisdictional efforts to address the mercury concern, in 1997 Ohio issued a general precautionary consumption advisory for women of childbearing age and children age 6 and under. They were advised to eat no more than one meal per week of any fish species from any Ohio body of water. In 2003, the advisory was extended to everyone. This was due to the presence of mercury at low background levels in nearly all Ohio fish samples tested. Due to frequency of consumption or traditional ethnic means of food preparation, subsistence anglers and certain cultural and immigrant groups may also be at greater risk of adverse effects due to contaminant exposure. More restrictive consumption frequency advisories are issued for these groups, such as the Ontario mercury advisory for subsistence fishers.

The United States Environmental Protection Agency in 2001 issued a national mercury-based advisory that states: "If you are pregnant or could become pregnant, are nursing a baby, or if you are feeding a young child, limit consumption of freshwater fish caught by family and friends to one meal a week. For adults, one meal is six ounces of cooked fish or eight ounces of uncooked fish; for a young child, one meal is two ounces of cooked fish or three ounces of uncooked fish."

In 2004, the Food and Drug Administration (FDA) and U.S. EPA issued a nationwide joint consumer advisory on methylmercury in fish and shellfish that supersedes the 2001 advisory. The FDA and U.S. EPA want to emphasize the benefits of eating fish but suggest that women might wish to modify the amount and type of fish they consume if they are pregnant, planning to become pregnant, nursing, or feeding a small child. The advisory specifically lists species of fish and shellfish not to eat (shark, swordfish, king mackerel, tilefish). It advises eating up to 12 ounces a week of the more commonly eaten species that are lower in mercury (shrimp, canned light tuna, salmon, Pollock, catfish), and six ounces per week of albacore tuna. The third part of the advisory recommends to: "Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers and coastal areas. If no advice is available, eat up to six ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week. Follow these same recommendations when feeding fish and shellfish to your young child, but serve smaller portions."

Carp is the fish species most frequently identified in Lake Erie consumption advisories, although numerous other species are identified in various locations, particularly channel catfish and freshwater drum. The different species restrictions apply to particular sizes of fish, based on the results of fish tissue sampling and varying rates of bioaccumulation.

Since the BUIA for fish consumption was completed in 1998, the impairment status and chemicals of concern for fish consumption advisories have not changed. It appears that chlordane was listed as a cause of impairment in the LaMP 2000 report due to advisories in Pennsylvania. Pennsylvania continues to monitor for chlordane, but PCBs and

mercury are now the contaminants upon which advisories are based. What has changed, however, are the number and sizes of species listed and an expansion of the areas where fish consumption advisories are now in effect. In many cases the list of advisories has increased due to collection and examination of fish tissue from new areas, rather than new sources of contamination. Mercury has become fairly ubiquitous, even in areas where there are no direct sources, suggesting that atmospheric deposition is the probable cause. Most jurisdictions now have a general advisory to eat no more than one meal per week of fish from waters in their borders.

Web sites for each of the Lake Erie jurisdictions maintain current information on fish consumption advisories in their state or province. Check the following for specific information:

Michigan: www.michigan.gov/documents/FishAdvisory03_67354_7.pdf

New York: www.health.state.ny.us/nysdoh/fish/fish.htm

Ohio: www.epa.state.oh.us/dsw/fishadvisory/index.html

Pennsylvania: www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/FishAdvis/fishadvisory04.htm

Ontario: www.ene.gov.on.ca/envision/guide/index.htm

4.2.2 Summary of 1998 Wildlife Consumption Restrictions Beneficial Use Impairment Assessment

Wildlife contaminant research has been extensive in the Great Lakes, but generally as it pertains to wildlife, not human health. Of the Lake Erie jurisdictions, only New York has established criteria for implementing wildlife consumption restrictions, although Ontario and Michigan have done research to evaluate the potential need for consumption advisories for waterfowl. Public health advisories for human consumption of snapping turtles and waterfowl are in place statewide for New York. The contaminants causing these advisories are PCBs, mirex, chlordane, and DDT (New York State Department of Health 2002)

Update 2004

In 2002 and 2003, Ohio listed consumption advisories for snapping turtles in certain Lake Erie tributaries due to mercury, lead and PCBs.



Photo: Scott Gillingwater

4.2.3 Summary of 1997 Restrictions on Dredging Activity Beneficial Use Impairment Assessment

Between 1984 and 1995, 25 navigational areas around Lake Erie have been dredged. Twelve of the 25 areas that are dredged have required the dredged material to be disposed in a confined disposal facility (CDF) at some time during this period. Currently, seven of these sites (Ashtabula, Cleveland, Lorain, and Toledo, Ohio, and Detroit, Rouge River and Monroe, Michigan) require confined disposal for most of the sediment dredged from those areas. Because there are restrictions on disposal of dredged materials, this use is considered impaired. Water quality standards and criteria for disposal of sediments vary among jurisdictions, but throughout the basin PCBs, PAHs and heavy metals are the most commonly identified contaminants that dictate confined disposal. A PAH-contaminated site in the Black River (OH) was remediated in 1990 by dredging and remedial dredging is planned in at least three other sites around the basin.

Table 4.4: Summary of Lake Erie Navigational Dredging Activity 1984-1995, by Jurisdiction

Jurisdiction	Michigan	New York	Ohio	Ontario	Pennsylvania
# of Locations	4 locations 3 AOCs	1 location 0 AOCs	12 locations 4 AOCs	7 locations 1 AOC	1 location 1 AOC
Volume (cu. yd.)	3,585,200	101,400	20,928,600	788,135	177,800
Cost	\$25,642,900	\$382,800	\$71,007,700	\$4,801,400	\$502,300

2004 Update

A PCB-contaminated sediment remediation project was completed on the Rouge River in 2001. PCBs in fish have subsequently been reduced enough to change the “DO NOT EAT” advisory to a less restrictive one. One sediment remediation project on the River Raisin has been completed and another is underway along with additional sediment assessments. Another remediation project is underway on Harris Lake in the Clinton River AOC. An extensive sediment assessment project, particularly to document high levels of PAHs as the cause of a high incidence of tumors in bullhead, was completed on the Old Channel of the Cuyahoga River in 2003.

4.2.4 Summary of 1999 Recreational Water Quality Beneficial Use Impairment Assessment

Annex 1 of the Great Lakes Water Quality Agreement (GLWQA) states that: “*Waters used for body contact recreation activities should be substantially free from bacteria, fungi, or viruses that may produce enteric disorders or eye, ear, nose, throat and skin infections or other human diseases and infections*” (IJC, 1989). Annex 2 of the GLWQA lists “beach closings” as a beneficial use impairment related to recreational waters. According to the IJC, a beach closing impairment occurs “*when waters, which are commonly used for total body contact or partial body contact recreation, exceed standards, objectives, or guidelines for such use*” (IJC, 1989).

The major human health concern for recreational use of Lake Erie waters is microbiological contamination (bacteria, fungi, viruses, and parasites). Human exposure occurs primarily through ingestion of polluted water, and can also occur through the entry of water into the ears, eyes, nose, broken skin, and through contact with the skin. Gastrointestinal disorders and minor skin, eye, ear, nose and throat infections have been associated with microbiological contamination.

As noted above, recreational water quality impairment includes situations where partial body contact recreation standards are exceeded. To be complete, an assessment needs to evaluate all recreational water use activities where total or partial body water contact may occur. This includes primary activities such as swimming, windsurfing and water skiing, and also situations where swimming may occur in open waters during secondary contact activities, such as boating and fishing. The assessment considers both nearshore and open

water activities in its evaluation of impairment, thus, the change in title from *beach closings* to *recreational water quality impairments*.

Federal, state and provincial recreational water quality guidelines recommend bacterial levels below which the risk of human illness is considered to be minimal. When contaminant indicator levels in the bathing beach water reach levels that indicate contaminants may pose a risk to health, public beaches are posted with a sign warning bathers of the potential health risk. The primary tool to evaluate beach water quality is the measurement of *indicator organisms*, which indicate the level of bacterial contamination of the water. The two indicator organisms most commonly used to measure bacterial levels are *fecal coliform* and *Escherichia coli* (*E.coli*). High levels of fecal coliform or *E. coli* in recreational water are indicative of fecal contamination and the possible presence of intestinal-disease-causing organisms. However, it should be noted that neither *E. coli* nor fecal coliform testing differentiates between human or animal waste, or indicates the presence of viruses or of non-fecal contaminants (e.g. *Staphylococcus*).

Bacterial level exceedences are occurring at beaches throughout the Lake Erie basin. Therefore, Lake Erie basin nearshore recreational water quality is impaired from a human health (i.e. bathing use) standpoint. Bacterial levels data examined for the 1998

BUIA report provided support for a conclusion that recreational use of Lake Erie offshore is unlikely to be impaired by bacteria. However, based on a request from the Lake Erie Binational Public Forum, the Lake Erie LaMP has decided to classify the use impairment for recreationally used “open waters” as “inconclusive”, since a recent comprehensive data-set for open lake waters is not available for assessment.

Many sources contribute to microbiological contamination, including combined or sanitary sewer overflows, unsewered residential and commercial areas, and failing private, household and commercial septic systems. However, it is important to note

that simply because bacterial levels are present, it does not necessarily mean that sewage overflow is a problem. Other sources may be agricultural runoff (e.g. manure); fecal coliforms from animal/pet fecal waste washed into the lake or storm sewers by heavy rains; wildlife waste, as from large populations of gulls or geese fouling the beach; direct human contact, e.g. swimmers with illnesses, cuts or sores; or high numbers of swimmers/bathers in the water, which are related to increased bacterial levels; and direct discharges, illegal dumping of holding tanks of recreational vessels. Other factors affecting contamination levels are low (shallow) water levels; hot weather/higher temperatures; high winds that can stir up bacteria that are in the sediments; and calmer waters that can slow dispersal and create excess concentrations of bacteria.

Update 2004

Many beaches still experience beach closings throughout the recreational season. The U.S. Beach Act provides grants to the states to develop regular monitoring programs and the use of common standards to determine when a beach should be closed. A number of research studies are underway to define sources of beach contamination and also to develop monitoring methods that provide more timely results.



Photo: U.S. EPA Great Lakes National Program Office

4.2.5 Summary of 1997 Degradation of Aesthetics Beneficial Use Impairment Assessment

An aesthetic impairment occurs when any substance in water produces a persistent objectionable deposit, unnatural color or turbidity, or unnatural odor (e.g. oil slick, surface scum) (IJC, 1989).

For the Lake Erie LaMP process, the IJC listing criteria for evaluating aesthetic impairments in Lake Erie have been adopted with the following additions:

- Whether an aesthetic problem is *naturally* occurring or *man-made* does not affect its potential designation as an impairment;
- The fact that there is currently no known solution to an aesthetic problem does not affect its potential designation as impairment.

With the exception of beneficial use impairment assessments already completed for Lake Erie AOCs, Lake Erie aesthetic problems have not previously been evaluated collectively. In most cases the locations, frequency, duration, and magnitude of any identified aesthetic problems or impairments have not been regularly tracked through any formal monitoring program. In addition, there is no precise/common definition for a “persistent objectionable deposit.” Therefore, detailed information is largely anecdotal and inherently subjective.

The purpose of this assessment is to: a) outline all known instances of aesthetics problems in Lake Erie waters; b) evaluate the nature of these problems, where possible; and c) to distinguish between aesthetic impairments to use of Lake Erie, as defined by the IJC listing criteria, and other aesthetic issues of concern that do not meet the listing criteria.

The reappearance of the mayfly (*Hexagenia*) exemplifies the conflict between traditional indicators of improving ecosystem quality and perceived aesthetic problems. During the final stage of their life cycle, burrowing mayflies emerge from Lake Erie sediments and swarm in such large numbers that they have made roads slippery and caused temporary brown-outs. These swarms of mayflies are regarded as a signal of improving Lake Erie water quality, but create a temporary nuisance to humans. Because the mayfly is widely regarded as a signal of improving water quality, any aesthetic problems created by swarming have not been classified as an impairment in this assessment. However, it is acknowledged that there can be temporary conflicts between the improving Lake Erie ecosystem and certain desired human uses of the lake region during the mayfly-swarming period.

To date, the Lake Erie LaMP process has identified the following list of potential aesthetic problems: high turbidity, obnoxious odor, excessive *Cladophora*, excessive blue-green algae, nuisance conditions at public beaches/lake shoreline, excessive aquatic plants washing up onto beaches and shorelines, floating garbage/debris, and dead fish.

4.3 Impairments Caused by Chemical Contaminants

4.3.1 Overview

Both contaminant loadings to the lake and contaminant levels in biota have decreased from levels recorded in the 1960s and 1970s. However, Lake Erie still contains a legacy from the past in the form of contaminated sediments that were deposited before bans on the use of certain chemicals and pollution reduction initiatives were implemented. Contaminants are clearly bioaccumulating in Lake Erie biota on a continuum from benthos to fish to amphibians, reptiles, birds and mammals, resulting in the specific impairments summarized in Tables 4.5 through 4.7. In addition, the filter feeding habits of the non-native invasive dreissenids are re-introducing contaminants not previously biologically available back into the water column and ultimately into the food web.

The information in this section is organized by trophic level (benthos, fish, birds, and mammals) to more clearly illustrate the biomagnification concept. Benthic organisms spend most or all of their lifecycle in the sediment of the lake. Some fish are benthic feeders or spend most of the time near the bottom; others eat organisms that have spent part of their lifecycle as benthos. Finally, birds and mammals prey on the fish. Each organism has

4.2.5.1 Impairment Conclusions

Table 4.5: Summary of 1997 Lake Erie Aesthetic Impairment Conclusions

Type of Impairment	Determination of Impairment	Location/Extent of Impairment	Known Causes of Impairment	Notes
High Turbidity	Impaired.	Maumee, Rouge River and River Raisin AOCs - western basin; Black and Cuyahoga (navigation channel) AOCs - central basin.	Agricultural and urban point and non-point source runoff and storms stirring up bottom sediments.	
Obnoxious Odors	Impaired due to dead fish and <i>Cladophora</i> ; Inconclusive decaying zebra mussels.	Cuyahoga AOC - central basin (fish); <i>Cladophora</i> fouling has occurred at Lake Erie State Park Beach, New York and Rondeau Bay, Ontario.	Decaying algae and fish.	Although decaying zebra mussels and CSO discharges of raw sewage are known to cause obnoxious odors, it appears from information to date that these problems are not persistent in Lake Erie.
Excessive <i>Cladophora</i>	Impaired.	Eastern and central basin nearshore - nearshore and river mouths in Ontario waters (eastern basin) and Rondeau Bay, Ontario (central basin).	Nutrient enrichment, availability of substrate.	
Blue-green Algae	Inconclusive.	Western basin.	Emerging issue. Research is underway to pinpoint cause of <i>Microcystis</i> bloom. Hypothesis that zebra mussels may be contributing to the problem.	It is not known whether extensive <i>Microcystis</i> blooms will continue to persist. Therefore a definitive impairment determination has not been made.
Aquatic Plant Deposits at Public Beaches	Not Impaired/ No documentation to date showing a persistent problem.	N/A	N/A	
Zebra Mussel Shells at Public Beaches	Inconclusive.	Large deposits of shells have been reported at many western basin beaches and at Presque Isle Bay State Park, central basin.	Deposits of zebra mussels/ shells.	It is not known whether reported problems are persistent and, if so, if they are interfering with human use of shoreline areas.
Floating Garbage and Debris	Impaired.	Geographic extent of impairment is localized, Cuyahoga AOC, Headlands Dune State Nature Preserve - central basin.	Large quantities of floating debris (primarily natural), Cuyahoga AOC; interfering with navigational, recreational, and industrial use of affected area in Cuyahoga AOC. Large quantities of floating garbage (primarily CSO-related) have led to citizen complaints at Headlands Dunes State Nature Preserve.	This issue is significant enough for the Cuyahoga AOC that a proposal to purchase a debris harvester is being pursued.
Dead Fish	Impaired.	Geographic extent of impairment is seasonal and localized. Cuyahoga AOC - central basin, Ontario eastern basin waters are only documented impairments to date.	Seasonal die-offs due to alewife/other exotics not acclimated to colder water temperatures.	

N/A = Not Applicable

bioaccumulated contaminants during its lifecycle, and the effect magnifies as one moves up the food chain. There are species used as indicators of this phenomenon (midges, mayflies, brown bullhead, bald eagle and herring gull) for which we have the most information. However, the list of species used to monitor contaminant impacts has grown in recognition of widespread bioaccumulation.

It should be noted that contaminant studies tend to look at effects to a particular organism in a particular location versus population-wide effects. But when evidence from the ecological impairments (section 4.4) is combined with toxicological results, it can be seen that contaminants are often an important limiting factor to population health.

4.3.2 Summary Conclusions

Lake Erie basin impairments caused by chemical contaminants include restrictions to fish and wildlife consumption, restrictions on dredging activity, fish tumors or other deformities (section 4.3.4), bird and animal deformities or reproduction problems (section 4.3.5), and benthic deformities (section 4.3.3). Impairment conclusions for restrictions to fish and wildlife consumption and restrictions on dredging activity are summarized in section 4.2, human use impairments. The rest are summarized below.

PAHs, PCBs, DDE, DDT, mercury, lead, chlordane, dioxins, mirex, dieldrin, and nitrates are all demonstrated to be causing impairment to fish and/or wildlife. As a result, most of these chemicals have already been identified as LaMP pollutants of concern for source trackdown. In particular, PCBs and mercury have been designated as critical pollutants for priority action in the Lake Erie LaMP.

4.3.3 Summary of 2001 Benthos Beneficial Use Impairment Assessment

Benthos refers to the suite of organisms that live on or in the lake bottom, referred to here as macroinvertebrates. Because macroinvertebrates live in close association with the sediments and are relatively immobile, they are good bioindicators of levels of persistent compounds in the sediments, especially trace metals and organic chemicals (pesticides, petrochemicals, PCBs, PAHs, etc.). Therefore, one of the criteria used for assessing benthic impairment is when toxicity of sediment-associated contaminants at a site is significantly higher than reference controls.

Highly toxic sediments produce profound, but sometimes non-specific, reductions in benthic abundance, richness (numbers of species), and community composition. Lower levels of contaminants may cause sublethal effects in invertebrates, just as they do in vertebrate animals (impairment of growth or development, morphological deformities, chromosomal abnormalities, or production of stress proteins). Contaminant breakdown products are often more toxic than the parent compounds. However, some benthos may tolerate persistent compounds because they lack the ability to break the pollutants down into compounds that can be excreted. Because benthic invertebrates may bioaccumulate these toxic compounds, their body burdens can serve as indicators of the amount of bioavailable contaminants in the environment, and of the transfer potential to predators at higher trophic levels (fishes, birds, etc.). Bioaccumulation factors for some chemicals can be extrapolated to anticipate whether burdens of top predators are likely to approach toxic thresholds.

For the Lake Erie LaMP assessment, the benthic communities found in contaminated sediments may be designated impaired if one or more of the following occur:

- The community is degraded;
- Bioassays using sediment from an area indicate toxicity to benthic organisms;
- Macroinvertebrates collected from the sediments have significantly elevated incidences of deformities or other abnormalities;
- The contaminant burden of benthic animals is great enough that predators may be at risk of bioaccumulating toxic concentrations of the contaminants.

Impairment was assessed in each of six lake zones: tributaries, wetlands, shorelands, embayments, nearshore and offshore. Conclusions, by basin and zone, for benthic impairments due to contaminated sediments are summarized in Table 4.6. Benthic impairments that are due to causes other than contaminated sediments are addressed in section 4.4.

Table 4.6: 2001 Summary of Benthic Impairments Caused by Contaminated Sediments

Lake Erie Zone	Lake Erie Basin	Type of Impairment
Tributaries	Eastern - Buffalo River	Contaminated sediments; elevated incidence of mouthpart deformities in midges
	Eastern - Grand River, Ontario	Chemical contamination
	Central - Black, Cuyahoga and Ashtabula Rivers	Contaminated sediments
	Western - Detroit, Raisin, Ottawa and Maumee Rivers and Swan Creek	Contaminated sediments
Embayments	Central - Black, Cuyahoga and Ashtabula Rivers	Harbors dominated by pollution tolerant benthos
	Western - Maumee Bay, Toledo Harbor	Contaminated sediments
Nearshore (< 5 m depth water up to 4 km from shore)	Western - Detroit and Maumee Rivers	Elevated incidence of mouthpart deformities in midges
Offshore (> 4 km from shore)	Western - Detroit River discharge current	Low <i>Hexagenia</i> population density appears to parallel discharge current band; this needs to be confirmed with maps
	Western - Monroe	Adult <i>Hexagenia</i> collected in 1994 had the highest contaminant burdens (PCBs, other organochlorines, pesticides) of any Lake Erie samples
	Western - Middle Sister Island	<i>Hexagenia</i> larvae had high burdens of organochlorines and PAHs

4.3.4 Fish Contaminants

4.3.4.1 Overview

In Lake Erie and its tributaries, mercury, PCBs, lead and dioxins are causing fish consumption advisories. PAHs, and potentially other compounds, in contaminated sediments are associated with fish tumors and other deformities. The purpose of fish consumption advisories is to minimize potential adverse impacts to human health (section 4.2). However, the contaminant data that support the advisories can also be used as a tool to assess fish and wildlife health. For example, contaminant levels in fish are used to develop bioaccumulation factors used in assessing contaminant impacts to fish-eating birds, mammals, amphibians, and reptiles (see section 4.3.3).

The purpose of assessing the prevalence of fish tumors and other physical abnormalities is to use these as an indicator of both environmental degradation of the aquatic ecosystem and a measure of health impairment to fish populations. However, this assessment of fish health is limited to fish deformities caused by xenobiotics such as PAHs, which do not bioaccumulate. Therefore, the potential impacts of bioaccumulative chemicals on other aspects of fish health, such as reproduction, are not covered. The LaMP acknowledges this data gap and hopes to address it in more detail in the future.

The assessment criteria require identification of fish tumor or deformity impairments: a) regardless of whether a specific cause for the tumor has been identified, b) regardless of whether a cause, when identified, is a chemical pollutant and/or carcinogenic, and c) regardless of whether a tumor is a carcinoma. Only data for types of tumors suitable as impairment indicators were used for this assessment (excludes genetically and virally induced tumors). All sites where fish tumor data suitable for indicating impairment existed, and tumor prevalence exceeded rates at least impacted sites in the Lake Erie basin, were classified as impaired as summarized in Table 4.7.

Where brown bullhead tumor impairment occurs, it is typically correlated with elevated concentrations of PAHs. Because brown bullhead are benthic fish and remain in a specific geographic location during their lifespan, tumors are indicative of local sediment conditions.

In surveys of other fish species, although the causes of tumor or deformity impairment are unknown, the presence of more mobile fish species points to broader environmental degradation (versus locally contaminated sediments) as the source of the problem.

Update 2004

Following the 1990 removal of PAH-contaminated sediments from the lower Black River (OH), tumors in brown bullhead have improved to the point that the RAP has submitted an application to U.S. EPA to re-designate the fish tumor BUIA from impaired to “in recovery”. While the exact cause(s) of the tumors in brown bullhead in the Presque Isle Bay (PA) AOC remains unclear, the tumor rates have improved to the point that the AOC is now rated as an “Area in Recovery.”

Table 4.7: Summary of Fish Tumor or Deformity Impairments from BUIA (Baumann et al. 2000)

Basin	Impairment
Western Basin Nearshore	Impaired in 6 tributaries, the Lake Erie islands, and along the Lake Erie shoreline in 2 Ohio counties
Western Basin Offshore	No conclusive documentation of impairment (e.g. freshwater drum tumors)
Central Basin Nearshore	Impaired in 13 tributaries, 1 bay, and along the Lake Erie shoreline in 4 Ohio counties
Central Basin Offshore	No data available to assess impairment
Eastern Basin Nearshore	Impaired in 1 tributary and 1 bay
Eastern Basin Offshore	No conclusive documentation of impairment (e.g. freshwater drum tumors)

4.3.5 Summary of Animal Deformities or Reproductive Problems Beneficial Use Impairment Assessment (Grasman et al. 2000)

Toxicological wildlife survey data are used throughout the Great Lakes to confirm the presence of deformities or other reproductive problems in sentinel wildlife species in a particular location. Therefore, by definition, the presence of these problems is enough evidence to confirm that impairment is occurring and is a good indicator of both wildlife health and potential adverse impacts due to contaminants. This assessment is not intended to assess population-wide impairments. Those issues are covered in the degradation of wildlife populations’ assessment (see Table 4.8).

Because wildlife toxicology surveys are often designed to determine conditions in the Great Lakes basin as a whole, this assessment varies from others in the amount of Lake Erie specific data available and its ability to report results by Lake Erie basin. In addition, the Lake Erie basin populations of some of the species examined such as bald eagle and colonial waterbirds nest primarily in the western basin. Others such as the river otter were extirpated from the Lake Erie basin prior to the 1900s and have only recently been reintroduced by wildlife management agencies. The most abundant data are available for Lake Erie bald eagle and herring gull populations that have been surveyed annually since 1980 and the early 1970s, respectively.

A combination of lowest observable effect concentrations (LOECs), population recovery objectives, and physiological biomarkers were used to establish the scientific weight of evidence for impairment. Ecoepidemiological criteria were used to establish cause-effect linkages, where possible. Reproductive, deformity, and physiological impairments are identified and associated with chemical causes, where known, in Table 4.8. These results indicate that some type of impairment is either clearly or likely occurring in all groups assessed, except for tree swallows. As noted below, tree swallows are very resistant to the effects of chemical contaminants, and may therefore be a poor indicator species.

As noted earlier, per the IJC listing criteria, this assessment is not required or intended to determine whether population-wide effects are occurring due to the identified impairments. Reproductive effects do not immediately or always translate into population effects. For example, if a population is near its carrying capacity (point at which species is in equilibrium with its environment), then there may not be enough resources (food, nesting habitat, etc.) for all young to survive to reproductive age. Hence, up to a point, a decrease in production

Table 4.8: Summary of Bird and Animal Deformity or Reproductive Beneficial Use Impairment Assessment Completed in 2000

Species/ Species Group	Impaired?	Type of Impairment	Likely Cause*	Notes
Bald Eagle	Yes, observed; exposure above effect levels	Reproductive & Deformity	R - PCBs, dieldrin, DDE D - PCBs	Extent of impairment is probably obscured by hacking/fostering and immigration from less contaminated inland territories
Colonial Waterbirds (herring gulls, double- crested cormorants, common and Caspian terns)	Yes, observed in herring gulls; exposure above effect levels in herring gull, cormorant and common tern eggs	Reproductive, Deformity and Physiological - immune system, reproductive organs, thyroids, liver enzymes, vitamin A, and porphyrins**	R - PCBs and possibly other chemicals D - PCBs P - PCBs, other organochlorines	Cause of recent reproductive failures of herring gulls on W. Sister Is. may include PCBs, microcystin, and (or) other factors Tree nesting cormorants are hard to study, but contaminant concentrations are among highest in Great Lakes and are likely associated with embryonic mortality and deformities Although Caspian terns have attempted to colonize Lake Erie as recently as 1996, they are still too rare in the basin for field study
Tree Swallow	Possible	Possible Physiological - reduced Liver vitamin A	P - PCBs	Significant organochlorine exposure; resistance to effects may make swallow a poor indicator species compared to other insect-eating songbirds
Mink	Likely; PCBs in food above effect levels	Likely Reproductive and Physiological	R - PCBs P - no data	
Otter	Insufficient data, but likely based on predicted high levels of exposure	Likely Reproductive	R - PCBs	Too rare in Lake Erie basin for study as they have just recently been re-introduced
Snapping Turtle	Likely - not observed, but exposure at some Ohio sites above effect levels	Likely Reproductive, Deformity, Physiological	R - PCBs, other organochlorines D - PCBs, other organochlorines P - organochlorines	
Spiny Softshell Turtle	Yes, observed; exposure above effect levels	Reproductive	R - PCBs, other organochlorines	
Frogs/Toads	Likely (see notes)	Likely Reproductive	R - DDE, nitrates	Nitrate concentrations in Lake Erie watershed often exceed lethal and sublethal concentrations for amphibians studied in laboratory experiments
Mudpuppies	Yes, observed	Deformity	D - PAHs and organochlorines	

* R = Reproductive Impairment; D = Deformity Impairment; P = Physiological Impairment

** Porphyrins - the liver synthesizes heme for hemoglobin and certain enzymes. Some organochlorines block this process by causing the accumulation of highly carboxylated porphyrins.

of young due to a contaminant may not affect adult population size because many young would have died anyway. However, if the population is below its carrying capacity, a decrease in production of young may prevent the population from reaching carrying capacity. In this situation, the impairments summarized in Table 4.8 can become more significant when all stressors to a particular species group are summed (contaminants, habitat loss, exotics, etc.). It is interesting to note that the results of the degradation of wildlife populations' assessment for these same groups of animals conclude that impairment is also occurring at the Lake Erie basin sub-population level.



Photo: U.S. Fish & Wildlife Service, James Leupold

4.3.5.1 Nitrates

Nitrates are nutrients and do not bioaccumulate. However, at higher concentrations they have been shown to cause effects in amphibians that are similar to those caused by toxic contaminants. Because less research and monitoring data is generally available for amphibian populations as a group, the mechanisms for the observed biological effects of nitrates are not as clearly defined as those for other organisms. A short summary of what is known is provided below.

A review by Rouse et al. (1999) evaluated the risk of direct and indirect effects of nitrate on amphibian populations. This review used a simple comparison of known environmental nitrate concentrations in North American waters to nitrate concentrations known to cause toxicity in a laboratory setting to amphibian larvae and other species that play an important role in amphibian ecology.

Lethal and sublethal effects in amphibians are detected in laboratory tests at nitrate concentrations between 2.5 and 385 mg/L (Table 4.9). Amphibian food sources such as insects and predators such as fish are also affected by elevated levels of ammonia and nitrate in surface waters (Rouse et al. 1999). This may have important implications for the survival of amphibian populations and the health of food webs in general.

Environmental concentrations of nitrate in surface waters in agricultural watersheds around Lake Erie ranged from 1 to 40 mg/L. Of 8000 water samples from rivers in the watersheds of Lake Erie and Lake St. Clair in the Canadian Great Lakes and in US states in the Lake Erie watershed 19.8% had nitrate levels above 3 mg/L. This concentration was known to cause physical and behavioral abnormalities in some amphibian species in the laboratory (Rouse et al. 1999). A total of 3.1% samples contained nitrate levels that would be high enough to kill tadpoles of native amphibian species in laboratory tests (Rouse et al. 1997).

4.4 Ecological Impairments

Ecological beneficial use impairments are intimately interconnected, and in Lake Erie include: degradation of fish, wildlife, phytoplankton and zooplankton populations; loss of fish habitat, loss of wildlife habitat; eutrophication or other undesirable algae; degradation of benthos; fish tumors or other deformities; and bird or animal deformities or reproduction problems. Therefore, the status of these beneficial use impairments needs to be integrated to develop a more comprehensive understanding of stressor impacts to the system as a whole. The results of beneficial use impairment assessments for fish tumors or other deformities, bird or animal deformities or reproduction problems, and benthic impairments caused by chemical contaminants are covered in detail in section 4.3, but are also mentioned in this section because dysfunction in the ecosystem is caused by contaminants as well as other stressors. Table 4.10 summarizes both the types of impairment and impairment conclusions for the noncontaminant related ecological impairments.

Table 4.9: The Toxicity of Nitrate to Amphibians (Rouse et al. 1999)

Species	Stage	Endpoint	Concentration of Nitrate (mg/L)
<i>Bufo americanus</i>	Tadpole	96h-LC50	13.6 & 39.3
<i>Pseudacris triseriata</i>	Tadpole	96h-LC50	17
<i>Rana pipiens</i>	Tadpole	96h-LC50	22.6
<i>Rana clamitans</i>	Tadpole	96h-LC50	32.4
<i>Pseudacris triseriata</i>	Tadpole	Developmental	2.5-10
<i>Rana pipiens</i>	Tadpole	Developmental	2.5-10
<i>Rana clamitans</i>	Tadpole	Developmental	2.5-10
<i>Bufo bufo</i>	Tadpole	96h-LC50	385
<i>Bufo bufo</i>	Tadpole	Developmental	9
<i>Bufo bufo</i>	Tadpole	Death	22.6
<i>Litoria caerulea</i>	Tadpole	Developmental	9
<i>Litoria caerulea</i>	Tadpole	Death	22.6
<i>Rana temporaria</i> *	Adult	EC50-paper	3.6 g/m ²
<i>Rana temporaria</i>	Adult	EC50-soil	6.9 g/m ²

* Frogs were placed on moist paper or soil spread with ammonium nitrate granules

LC50=lethal concentration required to kill 50 percent of the test population within 96 hours

EC50=lethal concentration for 50% of the population

The ecological beneficial uses were assessed in relation to historical conditions, existing management goals and objectives, out-of-system references (where available), and recent concerns, as applicable. Impairments occur to all of the beneficial ecological uses of the lake.

To fully understand the causes of impairment as outlined below, it must be understood that population impairments are often a subset of habitat impairments. Therefore, this ecological use synthesis starts by addressing habitat to document the causes and extent of impairment. The underlying causes (stressors) of the habitat degradation are examined. Habitat impairment information is grouped by stressor because each stressor generally affected a broad range of habitat types.

Population information is organized by impairment results, rather than by stressors causing impairment, because population impairments integrate across trophic levels to the whole ecological community. One of the criteria for determining habitat impairment is inability to support healthy benthos, plankton, fish, and wildlife populations. So, when the status of these populations is summarized, lost and degraded habitat is one of the key causes of population impairment.

The key reasons for habitat impairment, called primary stressors, are hydrology changes associated with land use, nutrient and sediment loads, invasion of non-native species, and contaminants. All of these primary stressors are the result of human use of the Lake Erie environment. Due to the adverse impacts of primary stressors on the Lake Erie environment, some key secondary stressors have also emerged. For example, due to the irreversible loss of large areas of Carolinian forest habitat, black-crowned night herons and egrets are primarily restricted to breeding on the Lake Erie islands in the western basin. Here they compete for habitat with the booming double-crested cormorant population. The cormorant population is present because of protection from human disturbance and an abundant food supply of exotic pelagic fish (alewife, shad, smelt). The cormorant guano is killing the trees in which herons and egrets nest.

In this case, the primary stressor is changing land use that led to the loss of mainland habitat. The secondary stressor is the impact of the cormorant population on the island habitat that remains. Therefore, when examining causes of impairment and means of rehabilitation, it is important to understand the sequential interactions of stressors as well.

Table 4.10: Summary of Ecological Impairments

Impaired Use	Impairment Conclusions	Types of Impairment	Causes of Impairment
Degradation of Phytoplankton and Zooplankton Populations*	Impaired - entire <i>eastern basin</i> ; lake effect zones of certain <i>western and central basin</i> tributaries	<i>PHYTOPLANKTON</i> - <i>eastern basin</i> - total standing crop and photosynthesis are below the potential set by P loading in the nearshore; Loss of keystone species; Loss of trophic transfer to <i>Diporeia</i> <i>ZOOPLANKTON</i> - <i>eastern basin</i> - loss of dominant cold-water species; <i>Eastern and west-central basins</i> - reduction in mean size points to potential impaired trophic transfer; <i>West central basin</i> - <i>Bythotrephes</i> acts as an energy sink	Zebra and quagga mussel grazing; High planktivory
Degradation of Fish Populations*	Impaired in <i>all basins</i> (species impaired vary by basin)	Unmet fish population objectives**; Loss of spawning/nursery area; loss of population diversity; rare, threatened, endangered and special concern species; reduced predatory function; Unnaturally high fish community instability; Inefficient use of food web energy	Habitat loss and degradation; Non-native invasive species; Loss of forage fish availability; Overexploitation; Loss of native stocks/species, particularly keystone predators
Loss of Fish Habitat*	Impaired in tributaries, shorelands, and nearshore of <i>all basins</i> (note - nearshore includes entire western basin area)	Unmet fish habitat objectives**; Loss of habitat diversity & integrity; Loss of spawning/nursery areas; barriers to migration; Changes in stream temperature, water quality, and hydrology; high turbidity; loss of aquatic vegetation; changes to benthic species composition; <i>western and central basin</i> lake effect zones - habitat loss and degradation	Destruction and draining of wetlands; Dams, dikes, dredging/channel modifications, water taking; streambank/shoreline filling and hardening; sediment/chemical contaminant/nutrient loadings; Navigation/recreational boating activities; exotics (carp, purple loosestrife, <i>Phragmites</i>) <i>Cladophora</i> fouling (eastern basin nearshore)
Degradation of Wildlife Populations	Impaired in <i>all basins</i> Detailed case studies are being prepared for 20 species or wildlife groups (birds, mammals, amphibians and reptiles) to illustrate the key impairment issues affecting the larger group of wildlife species that use the Lake Erie environment	Unmet wildlife population objectives**; Population fragmentation, isolation, and instability; loss or reduction in species indicative of quality habitat; loss of source populations; Rare, endangered, threatened, and special concern species; accelerated rates of parasitism/predation; Competition between wildlife/non-wildlife uses of a given habitat; changes to ground temperature and moisture conditions in forested areas; loss of travel lanes; loss of range/area-sensitive species (e.g. amphibians & reptiles, rails, bitterns, sedge wrens, bald eagle)	Fire suppression; logging; destruction and draining of wetlands; high water levels, storm surges; dredging/channel modifications, water taking, streambank/shoreline filling, hardening and backstopping; sediment/chemical contaminant/nutrient loadings; navigation/boating activities; non-native invasive species (zebra mussel, carp, purple loosestrife, <i>Phragmites</i> , garlic mustard, Eurasian milfoil, hybrid cattail, mute swan, gypsy moth, Dutch Elm disease, Chestnut blight)

Impaired Use	Impairment Conclusions	Types of Impairment	Causes of Impairment
Loss of Wildlife Habitat	Impaired in <i>all basins</i> 16 major habitat types were assessed. 13 were impaired in all Lake Erie jurisdictions where they occur (open lake, islands, sand beach/cobble shore, sand dunes, submerged, floating and emergent macrophytes, wet meadow, shrub swamp, mesic prairie, upland marsh, mesic and swamp forests)	Unmet wildlife habitat objectives ^{**} ; habitat fragmentation and loss of niches; loss of diversity and integrity; population demands exceed available habitat (e.g. colonial waders that use the Lake Erie Islands); loss of stopover habitat along migratory corridors (birds, butterflies, bats); loss of cover for protection from predation; loss of or accelerated succession patterns; loss of area available for habitat expansion; loss of buffer functions between one habitat type and another; loss or reduction in quantity/quality of nesting/denning areas; loss or reduction in quantity/quality of food sources	Fire suppression; logging; destruction and draining of wetlands; high water levels, storm surges; dredging/channel modifications, water taking, streambank/shoreline filling, hardening and backstopping; sediment/chemical contaminant/nutrient loadings; navigation/boating activities; exotics (zebra mussel, carp, purple loosestrife, <i>Phragmites</i> , garlic mustard, Eurasian milfoil, hybrid cattail, mute swan, gypsy moth, Dutch Elm disease, Chestnut blight)
Degradation of Benthos	Impaired. <i>Eastern basin</i> - offshore waters; <i>Central basin</i> - tributary, shoreland, nearshore and offshore waters; <i>Western basin</i> - tributary, shorelands, offshore waters	Degraded benthic community (composition and interactions among components) compared to reference conditions; dominant species indicate degraded environment; Keystone species absent or nearly gone: <i>*all basins</i> - unionid mussels, <i>Gammarus</i> amphipods; <i>*east and central basins</i> - <i>Diporeia</i> amphipods; <i>*east and western basins</i> - fingernail clams; <i>*middle of western basin</i> - <i>Hexagenia</i> (mayflies); Unmet objectives for benthic density, biomass or productivity ^{**} ; toxicity to benthic organisms (section 4.3.1); elevated incidence of deformities or other abnormalities (section 4.3.1); contaminant burden is high enough that predators may be at risk of bioaccumulating toxics (section 4.3.1)	Contaminated sediments, non-native invasive species or exotics (zebra mussel, round goby, etc.), loss and degradation of habitat particularly in wetlands
Eutrophication or Undesirable Algae [*]	Impaired - Maumee Bay, lake effect zones of Maumee/Ottawa Rivers, <i>western basin</i> ; nearshore and river mouth areas of Canadian <i>eastern basin</i> Potentially impaired - lake effect zones of certain Ohio tributaries, <i>western and central basins</i> ; Rondeau Bay and nearby nearshore and river mouth areas, Canadian <i>central basin</i>	Excessive <i>Cladophora</i> (see Degradation of Aesthetics impairment conclusions), degraded fish communities in lake effect zones of certain tributaries, P levels above Canadian guidelines in tributaries, Dreissenid grazing resulting in improved light penetration in nearshore zones	Phosphorus Non-native invasive species

More detailed technical information is available on-line at <http://www.epa.gov/glnpo/lakeerie/buia/index.html>

^{**}See Section 4.1 for a discussion of existing objectives and their relationship to Lake Erie LaMP ecosystem objectives.



4.4.1 Habitat Impairments

4.4.1.1 Introduction

The IJC very broadly defined habitat as the “specific locations where physical, chemical and biological factors provide life support conditions for a given species.” Specifically, the IJC indicated that “habitat impairment occurs when fish and/or wildlife management goals have not been met as a result of loss of fish or wildlife due to a perturbation” of the habitat. Management goals have been developed for birds - North American Waterfowl Management Plan (NAWMP), National Shorebird Plan, and Partners in Flight - Flight Plan, and fish - Lake Erie Fish Community Goals and Objectives. In addition, when the IJC developed listing criteria for determining benthic impairment, they included a recommendation that ecosystem health objectives be developed using benthic community structure. This recommendation has been implemented by a number of Lake Erie researchers (particularly for keystone species) and the resulting *objectives* have become widely accepted in scientific circles, even though they do not yet reside in any formal management plan. For other organisms, key indicator species and/or community structure were examined.

To assess the quality of the habitat in the Lake Erie basin, the basin was divided into 18 regions of similar physical, chemical and biological structure. The present evaluations were based not only on the ability of the present habitat to support fish, wildlife, plankton and benthic populations (ecological function) and on local and lakewide objectives as prescribed by the IJC, but also on historical records/out-of-system references, and recent concerns. Table 4.11 summarizes our present information linking stressors and habitats.

Loss of natural area to human use (i.e. agriculture, industry, housing) is an impairment in all Lake Erie basin upland habitat types, and extends shoreward to include wet meadows, emergent macrophytes, interdunal wetland and unconsolidated shore bluffs. So much of the original habitat has been lost that fragmentation of habitat and the small size of remaining habitat have impaired mesic forest, swamp forest, shrub swamp, mesic prairie, wet meadow, and wetland complexes. Other stressors are further degrading the remaining natural habitat.

4.4.1.2 The Habitat Continuum

Habitat degradation in the Lake Erie basin is due to a number of stressors, acting in concert. Even if the most critical stressor were alleviated, complete recovery would not occur. Remediation will likely require improvement in a number of areas. Table 4.11 summarizes our understanding of the relationship between stressors, habitat impairment, and impacts to populations of benthos, fish and wildlife. Stressors are listed vertically by category (altered hydrology, changing land use, and other) and the major habitat types assessed in the Lake Erie basin are listed horizontally. Where X is used, the applicable stressor affects that

habitat for fish, benthos and/or wildlife. Where there is nothing in a cell, it means that the particular stressor does not significantly affect that particular habitat in the Lake Erie basin. In addition to integrating this information, the table is designed to provide a preliminary tool for developing an action agenda. Shore habitat definitions are presented in Table 4.12.

The 18 habitat types listed in Table 4.11 form a continuum of changing physical, chemical and biological structure along gradients of water/moisture, light penetration, and substrate type. In sheltered aquatic areas, habitat progresses from open water to submerged macrophytes, floating macrophytes, emergent macrophytes and then wet meadow and shrub swamp or mesic prairie as water depth and flooding decrease and light becomes more available. In exposed aquatic areas, the nearshore habitats progress from sand or cobble substrates below water to beaches, interdunal wetlands in the sheltered hollows behind the beach or fore-dunes, and sand dunes. These two suites of nearshore habitats absorb the wave energy during storm events, protecting the upland regions from the more severe flooding and erosion events that are present today in comparison with historical conditions. Degradation of the beach and wetland complexes has decreased their ability to absorb the force of storms and is considered a cause of impairment of the dunes, wet meadows, mesic prairie and forests. On land, the dunes and mesic prairie give way to mesic forest. In the uplands, swamp forest, marshes, bogs, fens and vernal ponds develop in depressions and kettles. A similar progression of habitats radiates out from the larger open water and marsh areas and sheltered regions of tributaries. The floodplains of the tributaries develop shrub swamp and swamp forest.

The interconnectedness of the habitats in the Lake Erie basin means that: 1) degradation in one habitat has consequences for adjacent or downstream habitats, and 2) stressors generally affect a range of similar or adjacent habitats across a gradient. Some stressors, such as contaminants and loss of habitat area, affect community function in a broad range of habitats. Because habitats are highly interconnected, many species do not spend their entire life cycle in one habitat. For example, many species of birds that are habitat specific during the nesting season utilize a completely different set of habitats during the migration periods and may winter in entirely different regions of the continent. Another example is northern pike that live among submerged macrophytes as adults, but breed in flood pools associated with tributaries. Their young live in the emergent vegetation. Turtles and snakes that live in marshes and swamps lay their eggs in nearby forest and beach ridges. To support intact fish and wildlife communities, it is important for the whole range of habitats to be present and naturally functional.

Tributaries provide an excellent example of the importance of the health, interdependence, and connectivity of adjacent habitats frequently emphasized in the beneficial use assessments (see Figure 4.1). Tributary flow regime (the magnitude, timing, duration, frequency, and rates of change of water movements within a watershed) is intimately connected with the watershed tablelands. Formerly, natural drainage patterns through wet forest and meadow habitat water retention areas controlled the amplitude and frequency of spring floods and maintained summer base flows. Cultural land use practices associated with settlement, deforestation, and agriculture increased drainage efficiency. The amplitude and frequency of spring flooding in basin tributaries increased, as well as the amount of physical energy entering the stream courses. Due to accelerated spring run-off with reduced groundwater recharge, summer base flows were reduced. The draw down of the water table for human use has reduced the flow of spring water to certain rivers in eastern Ontario. This has further reduced summer base flow in these systems and impaired the spawning reaches of cold-water anadromous fish, such as trout.

The damming of lake basin tributaries is almost universal in scope. Dams alter the connectivity of stream systems and are barriers to migrations and other ecological interactions. Dams with sediment trapping abilities alter the physical hydrology and sediment dynamics in downstream reaches. Floodplains provide periodic connectivity between stream channel habitats and those habitats in these aquatic/terrestrial transition zones. Native terrestrial and aquatic species that are dependent on floodplain habitats evolved in these unique systems under natural flow regime conditions. Floodplains also provide for retention and assimilation of sediments, nutrients, and contaminants that are carried in the stream flow. The loss of assimilation capacity in tributary floodplains and their associated wetland complexes affects

Table 4.11: Summary of the Stressors Affecting the Habitats in the Lake Erie Basin

Habitat Zone Stressor/Habitat Type	Aquatic Habitat			Shore Habitat		
	Open Water Offshore	Open Water Nearshore	Tributaries*	Islands	Sand Beaches Cobble Shore	Unconsolidated Shoreline
Altered Hydrology						
Altered groundwater - wells, logging			X			
High water levels - erosion, flooding		X		X	X	X
Lack of along shore sand movement		X			X	
Tributary flow		X	X			
Stream channelization		X	X		X	
Dams - sediment, water, barrier		X	X		X	
Draining			X			
Dredging	X	X	X		X	
Entrainment		X				
Heated effluent		X				
Changing Land Use						
Conversion to human use (e.g. farm)		X	X	X	X	X
Degradation of adjacent habitat		X	X		X	
Fire suppression						
Nutrient addition	X	X	X			
Increased sediment loads		X	X			
Hardening/development of shoreline		X	X	X	X	X
Backstopping/dikes		X	X		X	
Quarrying/mining/gas & oil wells	Possibly	X	X	X		
Logging			X			
Other						
Non-native invasive species	Quagga	Carp, Zebra	Carp	Dreissenids		Non-native plants
Contaminants	X	X	X			
Cormorants/Deer				X		
Loss of large mammals						
Direct human use of natural habitat (e.g. boating, hiking)		X	X	X	X	

*Tributary habitat includes floodplain forests and certain swamp forests.

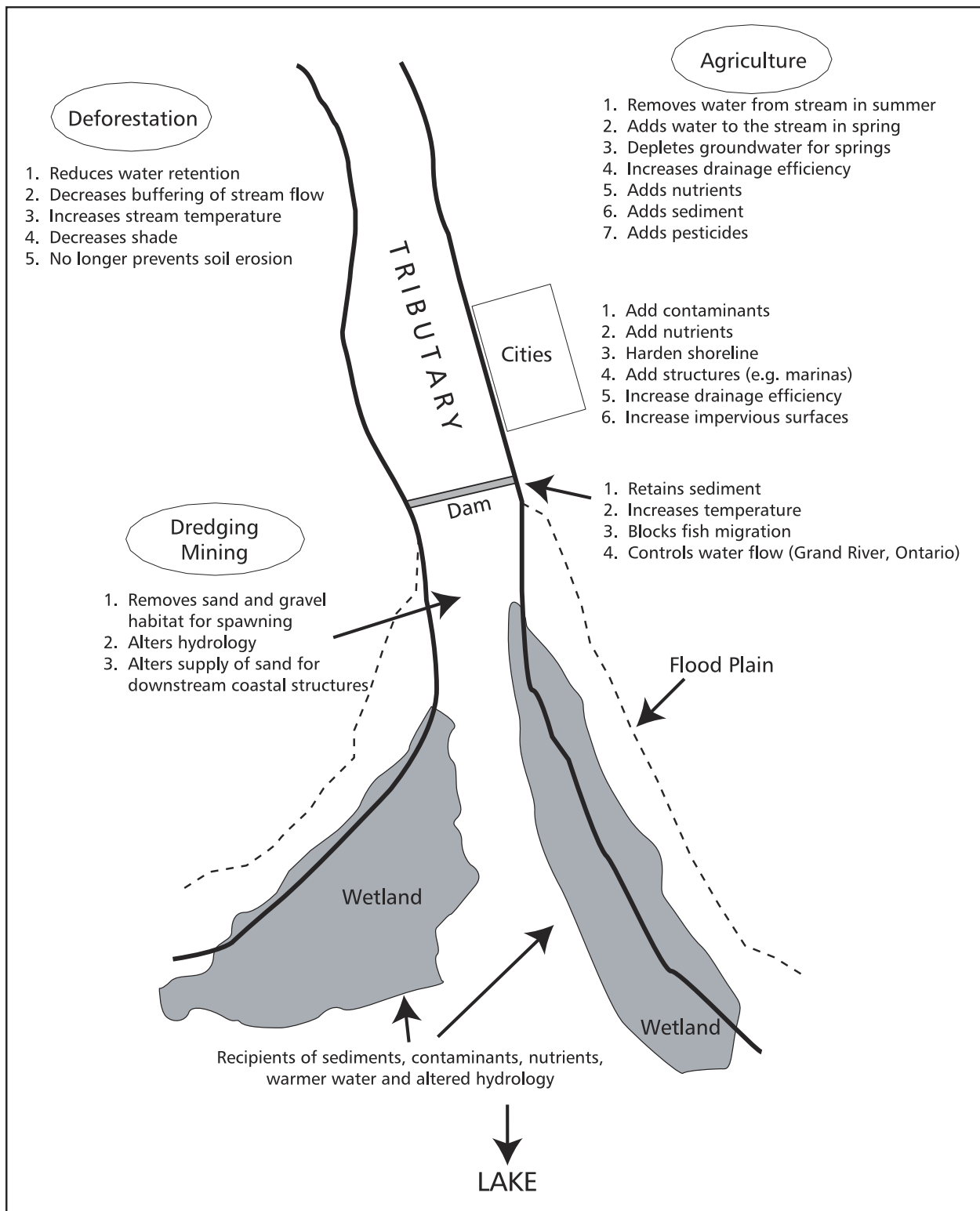
Habitat Zone Stressor/Habitat Type	Shore Habitat		Nearshore Habitat		
	Interdunal Wetland	Sand Dunes	Submerged Macrophytes	Floating Macrophytes	Emergent Macrophytes
Altered Hydrology					
Altered groundwater - wells, logging		X			X
High water levels - erosion, flooding	X	X	X	X	X
Lack of along shore sand movement	X	X			
Tributary flow			X	X	X
Stream channelization			X	X	X
Dams - sediment, water, barrier					
Draining	X	X	X	X	X
Dredging	X		X	X	X
Entrainment					
Heated effluent					
Changing Land Use					
Conversion to human use (e.g.farm)	X	X			X
Degradation of adjacent habitat	X	X	X	X	X
Fire suppression					X
Nutrient addition			X		
Increased sediment loads	X		X	X	X
Hardening/development of shoreline	X	X	X	X	X
Backstopping/dikes	X	X	X	X	X
Quarrying/mining/gas & oil wells					
Logging					
Other					
Non-native invasive species	Carp, Non-native plants	Non-native plants	Carp, Non-native plants, Mute swan	Non-native plants, Carp	Carp, Non-native plants
Contaminants					
Cormorants/Deer		X			
Loss of large mammals					
Direct human use of natural habitat (e.g. boating, hiking)	X	X		X	X

Habitat Zone Stressor/Habitat Type	Upland Wetland					Uplands	
	Wet Meadow	Mesic Prairie	Shrub Swamp	Bogs & Fens	Upland Marsh	Mesic Forest	Swamp Forest
Altered Hydrology							
Altered groundwater - wells, logging	X	X	X	X	X	X	X
High water levels - erosion, flooding	X		X				X
Lack of along shore sand movement							
Tributary flow			X				X
Stream channelization	X	X	X	X			X
Dams - sediment, water, barrier							
Draining	X	X	X	X	X		X
Dredging	X				X		X
Entrainment							
Heated effluent							
Changing Land Use							
Conversion to human use (e.g.farm)	X	X	X	X	X	X	X
Degradation of adjacent habitat	X	X	X	X	X	X	X
Fire suppression	X	X	X	X	X	X	X
Nutrient addition				X	X		
Increased sediment loads	X		X	X	X		X
Hardening/development of shoreline	X		X				
Backstopping/dikes	X		X				X
Quarrying/mining/gas & oil wells				X		X	
Logging						X	X
Other							
Non-native invasive species	Non-native plants	Non-native plants	Carp, Non-native plants	Non-native plants	Carp, Non-native plants	Non-native plants	Non-native plants
Contaminants							
Cormorants/Deer	X	X	X	X	Deer	Deer	Cormorant, Deer
Loss of large mammals	X	X					
Direct human use of natural habitat (e.g. boating, hiking)					X	X	X

Table 4.12: Definitions for Lake Erie Habitats

Habitat	Definition
Islands	With the exception of Mohawk Island, primarily limited to the western basin of Lake Erie. Permanent islands with rock bound shores below dolomite or limestone cliffs. Due to the moderating effects of surrounding lake waters, the climate of the islands has a greater range in annual mean temperature, less precipitation, smaller range of daily temperature, and a longer frost-free season than the neighboring mainland.
Sand Beaches/ Cobble Shore	Temporary open shorelands controlled by shifting sands and fluctuating water levels. Composed of rock fragments ranging from fine sand to large boulders. Devoid of or have minimal vegetation.
Unconsolidated Shoreline	Restricted to the eastern and central basins. Bluffs consisting of a rock or clay base with a thin topsoil layer along the top.
Interdunal Wetlands	An integral component of the marsh complex and the wetlands closest to the lake proper. Formed behind the active shoreline when lake levels have been stable enough to provide elevated dune areas. Wet pockets behind the foredunes or beaches and lakeward of the inner dunes or ridges.
Sand Dunes	Formed by deposits of sand and gravel along the lakeshore in areas that are no longer under the effect of the active wave zone. Three communities are found in the Lake Erie basin: a) grassland dune complexes; b) wooded beach ridge, and c) the sand barrens found on ancient beach ridges.
Submerged Macrophytes	Occurs in marsh and open lake settings. Characterized by pondweeds, milfoils, coontail, wild celery, and bladderworts that depend on water pressure/buoyancy for support of their thin, pliable stems.
Floating Macrophytes	A transition from open water habitat to emergent marsh vegetation. Occurs in shallow, protected water within streams and coastal marshes. Dominated by rooted plants with floating leaves such as water lily, spatterdock, water-lotus, water smartweed, and floating-leaved pondweeds.
Emergent Macrophytes	Consists of 2 community associations: a) robust emergents (cattail and hardstem bulrush) occurring lakeward, and b) narrow-leaved emergents (bulrushes, smartweeds, millets, burreed, rice-cutgrass, wild rice, etc.) occurring shoreward. Survive best in stable water levels, but can tolerate fluctuations for short periods.
Wet Meadow	Occurs as a band of vegetation in a transition zone above normal water levels. Soil is moist and may be inundated for a period of time sufficient to reduce the establishment of woody vegetation. Dominant species include bluejoint grass, northern reed grass, slough grass and sedges.
Mesic Prairie	A series of tall and short-grass prairie complexes governed by water availability. Historically fire prevented this habitat from succeeding to wooded habitat.
Shrub Swamp	Distinct from marsh in being dominated by woody vegetation (pussy and sandbar willow, swamp rose, meadow-sweet, silky dogwood, and buttonbush). Generally occur in glacial kettles or around the margins of lakes or marshes. Highly dependent on natural hydrology.
Bogs and Fens	Bogs are acidic, peat-accumulating, wetlands with as many as 5 distinct vegetative zones. Fens are also peat-accumulating wetlands, where mineral rich (alkaline) spring water comes to the surface, and typically have a marl zone dominated by sedges. Generally bogs and fens are successional habitats that naturally advance to upland habitats in the absence of intervention.
Upland Marsh	Found in low areas of the upland landscape in kettle lakes or pothole-type wetlands. All portions of the coastal wetland complex can also occur in upland marshes.
Mesic Forest	Mature stage of the deciduous forest consisting of oak-hickory and beech-maple communities. Historically, fire was a key controlling factor of this habitat type.
Swamp Forest	Consists of floodplain forest and deciduous swamp forest. Floodplain forests occur with stream and river channels that are at least periodically flooded, and common species include silver maple, cottonwood, sycamore, black willow, green ash, box elder, and Ohio buckeye. The typical dominant species of swamp forest include red and silver maple, black ash, swamp white and pin oaks.

Figure 4.1: Summary of impacts on tributaries from adjacent habitats and the impact of tributaries on downstream habitats



environments in interdependent nearshore zones (e.g. regions used by larval fish) and diverts the water, nutrients and sediments into the remaining wetlands, causing degradation of the wetland complex and nearshore regions of the lake.

Tributaries and their watersheds naturally provide a certain level of nutrients and sediments to the swamp forest in the floodplain, the lake and the wetland complexes. When the natural pattern of sediment and nutrient flow is altered, problems develop. Dams are a major reason for fish habitat impairments on tributaries. Dams trap the heavy sediments such as sand that are needed downstream to maintain beaches, sand bars and coarse-grained sublittoral habitats. Fine-grained sediments, from the erosion of topsoil, are suspended in the water and are released by dams. A certain amount of this material is needed by downstream vegetation as a source of minerals and nutrients. Too much can smother the vegetation through siltation and lead to eutrophic conditions. Dams not only trap sediment and water, altering both the upstream and down stream habitats, but also isolate populations and block the migration of anadromous fish to upstream spawning grounds. Dams are a major source of impairments on tributaries.

With deforestation the lack of shade, both along the river edge and in the fields that drain into the river, allows the river water to reach warmer temperatures that can be detrimental both to the biota in the river as well as in the downstream wetlands. Expected increases in temperature with climate warming will only heighten this problem. Thus tributaries are affected by activities in adjacent land-based habitats, and effects typically move downstream to the swamp forest, wetland complexes, sand beaches, littoral regions, and finally to the open lake.

Two general impairments are related to the transference of impacts from one habitat to another. First, the shoreline habitats each protect the next inland habitat from storm events. They were each considered impaired due to the impairment of adjacent habitats. Second, modification of the hydrologic regime or water table in one habitat alters the hydrologic regime in all neighboring habitats in a cascading manner. Flowing water forms a geological continuum with a progression of habitat types that develop along the gradient in moisture. Changes in hydrology due to human activities (logging, clearing land, wells, draining, backstopping) have caused impairments in all terrestrial and marginal habitats.

4.4.1.3 Stressors of Aquatic and Terrestrial Habitats

Aquatic Habitats

High Water Levels, Backstopping

The development and maintenance of the nearshore water-based habitats is a dynamic process controlled by along-shore sediment (sand) load in currents, the degree of shoreline indentation and structure, water levels and storms. Historically, the nearshore habitats moved inland or lakeward in response to changes in water levels. One of the major stressors on nearshore habitats (wetlands, sand/cobble beaches, unconsolidated shore bluffs, interdunal wetlands and sand dunes) in the past 30 years has been high water levels, particularly when coupled with shoreline hardening or development. The shoreline habitats have not been free to move inland, but rather are trapped in a narrow area between the water and man-made structures. When shoreline habitats are trapped, they are much more susceptible to the impacts of strong storms that not only severely alter their physical features, but also flush out detrital and planktonic matter into the nearshore margins faster and in higher amounts than what normally occurs from the marshes.

Sand bars and wide stretches of beach and/or submergent vegetation normally dissipate the force of these storms. Dikes were built or improved in the 1970s to protect the remaining marshes along the south shore of the western basin, which otherwise would have been lost (Boggy Bottoms, Deer Park Refuge; Mallard, North Bay, West Bay, and Green Creek Clubs; Metzger, Magee, Navarre, Toussaint, Trenchard's, Rusk, Moxley, and Erie Marshes; Ottawa and Winous Point Shooting Clubs; Little Portage, Toussaint, Pickerel Creek, Willow Point, Pipe Creek, Pointe Mouillee, Cedar Point and Ottawa National Wildlife Refuges).

The vast biodiversity of the wetland wildlife communities are dependent on a vegetated wetland complex. Dikes to protect the remaining wetlands from the combination of high lake levels and backstopping (to protect human use areas from the lake), storm surges, and non-native invasive species (i.e. carp, purple loosestrife, and reed-canary grass), have been the only means of survival for these diverse communities.

While isolation of these wetlands from the lake has provided the sole remaining habitat for many wildlife, invertebrates and bird species, it has also impaired their use as fish habitat. Many fish species utilize wetlands at some point in their life. To fully rehabilitate the fish community in Lake Erie, coastal wetlands must be re-connected to the lake. An ongoing experiment is underway at the Metzger Marsh where a dike has been engineered to allow limited entry and exit to selected fish close to natural cycles in water elevation, while still protecting the marsh from storms and carp.

High water levels also promote more extensive erosion of bluffs and beaches. In the past, the resulting sand was carried along shore and used to maintain and build up new beaches, underwater sandbars and shoals, and dunes. Breakwaters and other structures built out into the water, as well as the armoring of shorelines with rip-rap and dikes, have altered the intensity and paths of water currents redirecting much of this sediment load to deeper waters. The beaches have become narrower and more vulnerable to storms and seiches. These changes have decreased the feeding, nesting and resting opportunities for shore and wetland birds and wildlife, and increased the likelihood of their disturbance by people and by domestic and wild animals.

Turbidity and Nutrients

Forestry, agriculture, sewage disposal and combined sewer overflows have caused unnaturally high inputs of nutrients and sediments to the lake in the past. Remedial actions have greatly reduced these inputs and their effects on the lake. Eutrophication is no longer considered a widespread issue in the open waters of the lake: phosphorus and chlorophyll *a* levels are close to objectives. Due to periodic anoxia, open waters of the central basin are dominated by tubificid benthos, an indication of impairment. Elevated phosphorus levels, high turbidity, degraded benthic communities (although improved over those in the 1960s), and the abundance of omnivorous fish indicate that tributary mouths are still degraded. Where nutrients have been measured excessive phosphorus remains a localized problem. Along with nutrients, sediment loading is still a problem in numerous tributaries particularly in the western half of the lake. The offshore waters of the western basin and south shore of the central basin still show residual effects of eutrophication. Benthic communities in these regions are still impaired based on the high densities of tubificid worms, although their densities have been declining through the 1990s. The recolonization of the western offshore regions by *Hexagenia* starting in 1992 is thought to be due to improved oxygen conditions and decreased contaminant concentrations in the sediment throughout much of the basin.



Fine sediments have fouled the gravel and coarse substrates in the tributaries, shoreland, and nearshore environments reducing their suitability and use as spawning and feeding areas for fish or habitat for invertebrates. Many river spawning stocks were lost due to a combination of fouled spawning shoals and dams, e.g. northern pike, sauger, muskellunge, whitefish, sturgeon and walleye. Populations in the open lake are now maintained largely by lake spawning stocks. Rehabilitation of streams is allowing the recovery of some walleye river stocks and development of naturalized populations of rainbow trout. Pacific salmon (coho and chinook) are a minor component of stream spawners.

Improvements in water clarity during the 1990s can be attributed principally to the high filtering capacity of dreissenid mussels that invaded the lake in the late 1980s. Their impact has been particularly strong in nearshore regions and has allowed the redevelopment of submerged macrophyte beds. Submerged macrophytes in the open lake are not considered impaired. This habitat type is still considered impaired in the tributaries and wetlands due to loss of area (e.g. insufficient area to support wildlife and fish needs), and invasion of non-native invasive plant species, but is definitely improving.

Contaminants

Contaminants, which enter the aquatic system through run off from the land, direct disposal and atmospheric deposition, presently degrade areas in the open lake, nearshore and tributaries, particularly in the western basin. Contaminant levels are sufficiently high in some regions of the lake that impacts have been observed in both the highest trophic levels (bald eagles, herring gulls, cormorants, and common tern) and the lower trophic levels (benthic invertebrates). Sediment contamination has been listed as an impairment to benthos in the mouths of the Buffalo, Niagara, Grand, Black, Cuyahoga, Ashtabula, Ottawa, and Maumee Rivers and Swan Creek. Degraded benthic communities with higher than normal levels of mouthpart abnormalities (a measure of toxic impact) have been found in the nearshore regions off the Detroit and Maumee Rivers. Adult *Hexagenia* collected from western basin nearshore regions had higher contaminant burdens than those offshore, further suggesting that nearshore environments have contaminant problems.

Contaminants were considered one of the causes for the loss of *Hexagenia* from the majority of the lake in the mid-1950s. Although the *Hexagenia* population has made a remarkable recovery, particularly in the western basin, starting in the early 1990s its densities remain low through the central section of the basin. Contaminants are hypothesized to be the cause, although dissolved oxygen levels and sediment type are also critical to successful *Hexagenia* reproduction. *Hexagenia* larvae from the region of Middle Sister Island had high burdens of organochlorine compounds and PAHs.

Non-native Invasive Species

Carp were introduced in the last century and are the most physically destructive of the wetland exotics. They root through soft sediments and macrophyte beds while feeding, resuspending sediments and disrupting stabilizing root systems in the process. Their activities magnify the nearshore sediment and turbidity impacts and reintroduce nutrients and contaminants buried in the sediments to the water column.

Eurasian milfoil has invaded submerged macrophyte beds, while *Phragmites*, purple loosestrife, reed-cannary grass and hybrid-cattail have invaded the emergent wetland habitats. These invasive species cause impairments because many grow as monocultures that are not suitable for use by native species, reduce habitat complexity and biodiversity, and are less nutritious for the native birds and wildlife. They are also more vulnerable to disease and other pests, as well as disturbance from fire and storms that would result in catastrophic loss of cover for all species.

Perhaps the most obvious and most significant non-native invasive species in Lake Erie are the two dreissenid mussels, the zebra and the quagga mussel. Apart from the effects of their filtering activity on water clarity that was mentioned earlier, their physical presence is altering the nature of hard and soft substrates in Lake Erie.

Terrestrial Habitats

The main causes of impairment in the terrestrial habitats were loss of habitat area, fragmentation, altered hydrology, logging, the invasion of non-native plant species, contaminants, and sedimentation of upland bogs, fens, marshes, and swamps. Logging has impaired the mesic and swamp forests. Removal of the largest (dominant) trees returns the forest to a lower successional state, decreases biodiversity of the entire system, removes food and nest/den sites, and opens up the canopy. Some of the losses of large trees with nesting cavities have been mitigated through nest box programs for such species as flying squirrels, wood ducks, bluebirds, and prothonotary warblers.

More sunlight can enter the forest, which increases the temperature of the leaf litter and dries the forest floor reducing the amount of wet habitat needed by the associated invertebrate fauna and amphibians. Non-native plants have invaded and often form monocultures through the forest. They include garlic mustard, Japanese knotweed, dame's rocket, buckthorn and, in moister areas, *Phragmites*, purple loosestrife and reed-canary grass. The impairments they cause are: insufficient area to support wildlife populations; loss of plant biodiversity in the habitat; loss of habitat complexity; and decreases in nutritional food sources for wildlife.

4.4.2 Fish, Wildlife, Benthos and Plankton Community Impairments

Many species or groups of animals living in the Lake Erie basin were found to be impaired. Impairments were determined on a number of bases: a) population objectives set for key fish, wildlife and benthic species which integrate community function (e.g. mayfly-*Hexagenia*) or represent important functional groups (e.g. diving ducks, top predators etc.), b) ecological function, c) historical records, and d) recent concerns. These translate into impairments in biodiversity, community stability, and food-web structure and function. The causes of these impairments were associated with altered or lost habitat, the invasion of non-native species, human disturbance, and contaminants (Table 4.11).

Contaminant impairment of wildlife was noted for the benthic community, benthic-feeding fish (tumors), fish eating birds, mudpuppies in tributaries and possibly for diving birds feeding on dreissenids. Impairments due specifically to contaminants are discussed in Section 4.3. The following sections examine impairments to biodiversity, community stability and food web structure and function, integrating effects across the different trophic levels where possible.

4.4.2.1 Biodiversity and Endangered Species

Biodiversity refers to the number of species supported by a self-sustaining community. Over time, biodiversity normally declines as a community/habitat becomes severely degraded because native species are often depressed or lost. In Lake Erie, habitat loss and degradation, human disturbance, commercial fishing, the introduction of non-native invasive species and contaminants have affected biodiversity.

Thirty-four species of fish have been given the status of rare, threatened, endangered, species of concern or extinct in Lake Erie. Some of these were dominant members of the historical fish communities. A large number of the dominant species in the Lake Erie aquatic community are now non-natives: smelt, alewife, gizzard shad, round gobies, white perch, rainbow trout, pacific salmonids, dreissenid mussels, *Echinogammarus*, *Cercopagis* and *Bythotrephes*. As these non-native species became dominant, the biodiversity of the historical fish, benthic, and plankton communities decreased. Smelt are linked to the decline of blue pike, lake herring, the large calanoid, *Limnocalanus*, the marked decrease in *Mysis*, and to the near demise of lake whitefish. The fish species mentioned above had been strongly affected by overfishing and habitat degradation prior to the arrival of the non-native smelt in the lake. Alewife, smelt and gobies are implicated in the loss of spoonhead, slimy and deepwater sculpins. Recent evidence suggests that contaminants, in particular 2,3,7,8-tetrachlorodibenzo-p-dioxin, may have been responsible for the final loss of lake trout from Lake Ontario, although the role of thiamine deficiency and the resultant early mortality syndrome (EMS) in larval fish cannot be ruled out. This opens the question of the possible roles of contaminants and diet in the loss of lake trout and other species from other Great Lakes. Dreissenids have eliminated the unionid and sphaeriid clams from all but a few



refuges in the coastal wetlands, and are hypothesized to be indirectly responsible for the loss of *Diporeia* from the eastern basin. *Echinogammarus* has replaced *Gammarus fasciatus*, itself an exotic, in many regions.

Wildlife species using wetlands for breeding habitats or as important migration stopover habitats make up the majority of rare, threatened, endangered, species of concern, or extinct species within the basin. For one jurisdiction over 80% of the listed birds (43 species), 40% of the listed mammals (2 species), and half of the listed reptiles (8 species) use the wetland or terrestrial habitats of the Lake Erie basin. Mammals such as snowshoe hare, rice rat, porcupine,

timber wolf, marten, fisher, mountain lion, lynx, elk, and bison have all been extirpated or extremely reduced in range and/or population in the Lake Erie basin. For many of these species, rehabilitation cannot be an option. Habitat diversity is so severely reduced or altered in most wetland and terrestrial habitats, coupled with negative impacts of exotic plants on native vegetation, that diversity of the plant community has changed, which in turn has reduced the potential diversity of the wildlife community.

4.4.2.2 Community Stability

Open Lake

The fish community is considered unstable for a number of reasons: loss of critical habitat; loss of stabilizing effect of top predators; overwintering mortality of non-native species (alewife, shad); competition between native and non-native species; and inefficient transfer of energy through the food web. The loss or degradation of critical spawning/nursery habitat has made reproductive success less predictable and leads to reductions and variability in year class strength of most species. The LaMP has yet to assess reproductive problems in fish. When this assessment is conducted it will address the potential for contaminant impacts on community stability through effects on reproduction. As mentioned in section 4.4.2.1, recent evidence suggests that 2,3,7,8-tetrachlorodibenzo-p-dioxin may have been responsible for the final loss of lake trout from Lake Ontario. This opens the question of the possible role of contaminants in the loss of species from other Great Lakes and in the present reproductive function. Given that contaminants are: a) causing problems with benthos and top predators, b) at high enough levels to cause fish consumption advisories, and c) associated with tumors in brown bullheads, it would not be surprising if they were affecting the productive capacity of some fish populations.

Native stocks of the historical keystone predators (walleye, sauger, blue pike, northern pike, muskellunge) in cool-water habitats were extirpated or markedly reduced during the period from 1930 to 1972. These species were responsible for maintaining the structure and stability of the fish and lower invertebrate communities. Walleye populations recovered through the 1980s. In recent years, walleye distributions (move to deeper waters) have changed as transparency has increased, reducing the community-structuring role of this species. Blue pike would normally occupy this habitat, but have been extirpated from Lake Erie and are now biologically extinct. Northern pike and muskellunge are still rare in many regions, leaving some nearshore areas without strong piscivore structuring. Smallmouth bass provide this function in areas of rock substrate.

Lake trout are maintained by stocking and thus their predatory function is not impaired (their reproduction function, however, is impaired). Fisheries managers are trying to maintain the predatory function in the lake through maintaining native walleye stocks, by stocking lake trout, and by controlling sea lamprey populations. The sea lamprey is a non-native species that, as an adult, is parasitic on larger fish. Sea lamprey control was introduced to

allow lake trout to reach sexual maturity, thereby making natural reproduction and self-sustaining populations possible. If the sea lamprey populations are not controlled they can: a) decimate the populations of larger fish, b) prevent lake trout rehabilitation, c) reduce the surplus fish for sport and commercial fisheries, and d) further decrease predator function and energy flow in the lake.

Sea lamprey control provides an excellent example of the potential conflicts involved in managing and trying to restore degraded systems. TFM is applied to tributaries to control the populations of juvenile sea lamprey, but it also kills other species of lamprey, mudpuppies, sculpin, and some invertebrates. Control of sea lamprey is imperative to the health of the fish community. Therefore, alternate strategies of sea lamprey control are presently being investigated by the Great Lakes Fishery Commission to reduce the use of TFM. Between 1990 and 1999, TFM use has been reduced by 39% Great Lakes wide and by 70% in the Lake Erie basin.

The non-native planktivorous fish, alewife and shad, are not well adapted to winter conditions in Lake Erie and often suffer overwintering mortality. The extent of that mortality is dependent on the severity of the winter, which is variable. Native fishes are better adapted to conditions in Lake Erie and are less susceptible to overwintering mortality. Therefore, the population size of native species is less variable and would provide a more stable food source to top predators than that of non-native species. Alewife and shad can outcompete native planktivores, and together with smelt are the dominant planktivores in the lake. With these species as dominants, the stability of the fish community has been decreased. The inefficient transfer of energy through the aquatic food web is discussed in section 4.4.2.3.

The benthic fish community is changing rapidly with the introduction of dreissenids that have altered benthic community structure and productivity, and of gobies that feed effectively on dreissenids and displace native sculpins. This community is not yet stable.



Photo: U.S. EPA Great Lakes National Program Office

Fish BUIA Update (from LaMP 2002)

The major point from the 1998 fish habitat BUIA was that the fish community was unstable due to loss of habitat, loss of top fish predator stocks, negative impacts of non-native invasive species and inefficient flow of energy through the food web. These factors continue to create instability in the Lake Erie fish community.

Since 2000, round gobies have spread throughout Lake Erie and have increased in abundance. They are now among the most abundant fish species on rocky substrates, feeding on a variety of organisms ranging from plankton to zebra mussels and other benthic invertebrates to fish eggs. They also have become a major prey of essentially all benthic fish predators, including smallmouth bass, yellow perch, walleye, and freshwater drum. In July 2001, the first tubenose goby was captured in western Lake Erie. Given the St. Clair River experience (where both tubenose and round gobies were initially found but round gobies eventually dominated), it is anticipated that tubenose gobies will not substantially add to the impacts of the round goby.

Walleye stocks should improve in the near future as Lake Erie's five fisheries management agencies support a Coordinated Percid Management Strategy, which will significantly reduce fishing mortality on walleye through 2003. The strategy also allows for the further development of adaptive fishery management on an interagency level. Strong walleye hatches in 1999 and 2001 should bolster the adult stocks in coming years with improved survival rates that result from reduced fishing. Yellow perch stocks should also benefit from the Coordinated Percid Management Strategy.

A five-year fisheries restoration program has been initiated by Ontario for eastern Lake Erie. In cooperation with the New York State Department of Environmental Conservation, Ontario is establishing regulations for conservative harvest, initiating a major stock assessment program, and implementing a program of fisheries inventory and habitat assessment for nearshore waters and lake-affected zones of rivers.

Positive signs in the western basin fish community are that white bass stocks appear to be increasing in abundance and prey fish populations have recovered from low levels during the mid-1980s. Increased populations of mayflies have increased the forage base for many fish species, including yellow perch. The silver chub, a benthic-feeding high-energy food source for other fish, is reappearing in abundant numbers. The silver chub practically disappeared from the lake simultaneously with the catastrophic decline of the mayfly in the early 1950s (Troutman, 1981). Coincidentally, silver chubs feed on zebra mussels. Trout-perch, another benthic species that declined dramatically in the 1950s, is also making a comeback. These changes suggest that the historic benthic-feeding community in Lake Erie is beginning to recover (Thoma, personal communication).

Terrestrial Communities

In terrestrial communities, loss of habitat, contaminants and human interference have resulted in degraded community structure, a loss of predatory function and thus decreased community stability. Fragmentation of habitat and the small size of the remaining habitat impair wildlife in mesic forest, swamp forest, shrub swamp, mesic prairie, wet meadow and wetland complexes. The loss of habitat has altered community structure and increased the intensity of the interactions (competition, predation) within the remaining habitat. The small habitat areas remaining often cannot support animals that require large territories, such as eagles from the beach ridges along the south shore of Lake Erie or bison that once inhabited the mesic prairie. Species also become concentrated in small habitats and are then more easily located and vulnerable to predators and parasites. Fragmentation of habitat is also a serious problem. It particularly affects smaller, less mobile creatures, such as amphibians, reptiles and insects. When habitats are fragmented, little or no migration occurs between isolated parts of the same habitat type. The resultant small, isolated populations are more susceptible to extirpation. Frogs and salamanders are impaired in interdunal wetlands, wet meadows, shrub swamps, upland marshes and swamp forests partly for this reason. Increased probability of extirpation, predation and parasitism, limited gene pools, and lack of top predators or larger mammals all result in decreased community stability.

The large deer population, loss of bald eagles from the system, small populations of coyote and the extirpation of carnivores such as wolves reflect a loss of top predators in the terrestrial as well as the aquatic community. The impact of range expanding species, such as the cormorant, also suggests a decline in community stability. Several bird populations have expanded greatly and are negatively impacting other species or groups.

The decline in mainland habitat of colonial water birds is pushing black-crowned night herons and egrets into competition with cormorants, which arrived in the Lake Erie basin earlier this century. The breeding population of cormorants in the Lake Erie basin is restricted to the islands in the western basin. The population is expanding and their guano has the potential to kill the trees in which they nest. The loss of mainland habitat is restricting black-crowned night heron and egret breeding to these same islands and trees. This shrinking habitat base raises long-term concerns for the future of these species. Cormorants can nest on the ground, but egret and heron require trees.

Increasing ring-billed gull populations have displaced common terns from historic nesting sites on beaches, islands, and dune areas and result in increased predation on remaining nesting colonies. This is considered an impairment because the population levels

of ring-billed gulls are elevated above historical levels, likely due to the additional sources of food provided by agriculture and human garbage. The piping plover is also impaired from increased ring-billed gull populations and other nest predators such as raccoons and skunks. Human disturbance has been a leading cause of extirpation of breeding piping plovers from the basin.

Black ducks prefer bog and fen type environments for breeding. Their population is impaired because it is below the objectives set by NAWMP. The recovery of black ducks is hampered by the large populations of mallard which outcompete them in the more open environment created by the altered land uses of the basin. Marsh management creates habitat more favorable for mallard breeding than black duck breeding. Bog and fen habitats cannot be rapidly created or restored for short-term recovery of black ducks.

Prothonotary warblers, which were considered as representative of the needs of a bird/amphibian complex, are impaired for the most part by habitat changes. However, their existence is jeopardized further by competition with exotic species (European starling, house sparrow) for nest sites and by nest parasitism by cowbirds.

On the positive side, bald eagle populations are increasing and expanding into new territories to nest. Colonies of great blue herons have been established in a number of tributaries in the U.S., and it is common to see the magnificent birds feeding in many shallow water habitats.

4.4.2.3 Altered Food Web Structure and Function

Aquatic Habitats (from LaMP 2000)

Dreissenids have radically changed the food web and in so doing are responsible for impairments to the benthos, plankton and fish communities. The high filtering capacity of dreissenids has probably impaired the phytoplankton community by decreasing phytoplankton biomass and primary productivity in nearshore regions of the eastern basin. This has translated into reduced zooplankton production in those regions and poor recruitment of young-of-the-year fish. Offshore in the eastern basin, dreissenids may be responsible for the decline in diatom species richness and biomass in the spring. An alternate hypothesis is that UVB radiation is responsible. The decline in diatoms is hypothesized to be responsible for the loss of *Diporeia* (benthic impairment), an important food source for fish (whitefish, young lake trout, and smelt) in the hypolimnion.

Dreissenids have also caused the loss of unionid mussels, sphaeriid clams and a shift of the offshore benthic community away from grazing and predacious invertebrates toward oligochaete worms. This new community is less able to support the historic fish community. Loss of *Diporeia* offshore intensified the predation of smelt on mysids and zooplankton. Strong predation on zooplankton by alewife and smelt has resulted in zooplankton communities composed of small species and in lower total zooplankton production.

The addition of *Bythotrephes*, a predatory zooplankter, has inserted another trophic level between herbivorous cladocerans and fish. *Cercopagis*, another predatory zooplankter, arrived in the last several years. This also decreases the efficiency of energy flow up the food web. The abundance of *Bythotrephes* in this planktivore-dominated system further suggests that *Bythotrephes* may be an energy sink. The zooplankton community in the eastern basin is not transferring energy to fish as efficiently as it might. Thus, in total, the food resources of fish in the eastern basin have been reduced. This food web disruption of the pelagia of the eastern basin is an impairment of the fish community as fish community goals and objectives for harvestable surplus fish cannot be met.

In addition to altering the food-base of the pelagic fish community in the eastern basin, dreissenid impacts on water clarity have affected the efficient use of this food by the fish community. The increased transparency of the water column has displaced the principal predator, walleye, from much of the habitat. The smelt population in the eastern basin is in poor condition. There is no longer efficient transfer of energy to a top predator. Thus, the surface waters of the eastern basin are impaired due to lack of a strong predator species that can utilize the habitat vacated by walleye. The food-web disruption of the pelagia due to dreissenids has been moving into the central basin. In the eastern and central basins, the decrease in smelt and rapid increase in gobies, which feed on dreissenids, is expected to affect predator feeding patterns and availability of predators to the fishery.

Photo: Mike Weimer, U.S. Fish & Wildlife Service



In the western basin, *Microcystis* blooms have developed in association with dreissenids. The cause of these blooms is being investigated and is hypothesized to be due to nutrient release by dreissenids. *Microcystis* is a blue-green alga that produces toxins and is not readily consumed by other organisms. After many years of being absent, blooms have appeared sporadically for a number of recent years over a wide area, and are therefore likely a signal of impairment.

Dreissenid impacts have also benefited some groups of plants and animals. Increased water clarity has allowed the expansion of submerged macrophyte beds, and therefore the expansion of northern pike, muskellunge and sturgeon populations associated with this habitat. These species are still rare in Lake Erie. The increased macrophyte beds should help protect the

emergent marshlands and provide new habitat for macroinvertebrates. Lake Erie is a critical staging area for diving ducks, such as mergansers, redheads, canvasbacks, and greater and lesser scaup, which use this habitat. Vegetation eaters, such as redhead and canvasback ducks, are showing wider use of sites. Mollusc eaters, such as scaup, are remaining for extended periods to feed on dreissenids. Mergansers are able to more efficiently feed on their small fish prey in the clearer water. Diving ducks, except for scaup, are meeting North American Waterfowl Management Plan (NAWMP) objectives and are not impaired.

Terrestrial Habitats

In the terrestrial communities, the invasion of non-native plants and harvesting of mast-bearing trees has altered the base of the food webs. Non-native plants, such as garlic mustard, Japanese knotweed, dames rocket, buckthorn and, in moister areas, *Phragmites*, purple loosestrife and reed-canary grass, often form monocultures thereby reducing the variety of foods and are often less nutritious than the native plants.

Direct human disturbance has also reached the point of impairing the wildlife population thereby affecting community and food web functions. Through recreational use of habitats, people and their pets have negatively impacted these sentinel groups/species: diving ducks, the common tern, piping plover, and other shorebirds, bald eagles, black terns, snapping turtles and eastern spiny softshell turtle. In some instances, animals are scared from roosting or feeding areas, which incurs an energetic cost. In other instances, the reproduction of the organism is affected, which incurs a population cost. Human disturbance was noted as a factor affecting wildlife in a number of different habitat types: open water, islands, beaches, bluff, interdunal wetlands, mesic prairie, mesic forests and swamp forests. Only in submerged and floating macrophyte beds, beaches, and sand dunes was human recreational activity impairing the habitat, per se.

4.5 References

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Section 5: Sources and Loads



Photo: U.S. EPA Great Lakes National Program Office

5.1 Approach and Direction

The Sources and Loads Subcommittee is charged with the task of identifying sources and loads of pollutants identified by the Lake Erie LaMP process. The Subcommittee continues to describe the status and trends in concentrations of pollutants, identify major pollutant sources in the basin, and provide an information base upon which to support sound management decisions for reducing, removing and eliminating these pollutants from the Lake Erie system.

The Subcommittee also works to identify information gaps, and recommend the information required to fill those gaps.

An initial list of chemicals selected for intensive review was identified by the beneficial use impairment assessment reports (Table 5.1). Two substances, PCBs and mercury, were designated as Lake Erie critical pollutants due to documentation that they created impairment across the basin, particularly in relation to fish and wildlife consumption advisories. As the Lake Erie LaMP progresses and specific problems and causes become better defined, additional chemicals may be designated as critical pollutants.

Table 5.1: Pollutants Causing Beneficial Use Impairments in the Lake Erie Basin

Beneficial Use Impairment	Causes of Impairment
Fish & Wildlife Consumption Restrictions	<i>Fish</i> – PCBs, mercury, lead, chlordane, and dioxins <i>Wildlife</i> – PCBs, chlordane, DDE, DDT and mirex
Fish Tumors or Other Deformities	PAHs
Bird or Animal Deformities or Reproduction Problems	PCBs, other organochlorines, dieldrin, DDE, PAHs, nitrates
Degradation of Benthos	Sediments contaminated with PCBs, other organochlorines, pesticides, PAHs
Restriction on Dredging Activities	PCBs and heavy metals
Eutrophication or Undesirable Algae	Phosphorus
Recreational Water Quality Impairment	PCBs ¹ , PAHs ¹ , Exceedances of <i>Escherichia coli</i> or fecal coliform guidelines

¹PAHs are the basis for a human contact advisory in the Black River Area of Concern (Ohio), and PCBs are the basis for a human contact advisory in the lower Ottawa River, part of the Maumee Area of Concern (Ohio). The human contact advisories were issued by the Ohio Department of Health and recommend that contact with the sediment or water in these areas be avoided.

Table 5.2: Contaminants Identified as Lake Erie LaMP Pollutants of Concern

Contaminant(s)	Common Source(s)
Organochlorine insecticides and biocides	
DDT ^{2,3,4,5,6,8} • DDD, DDE Chlordane ^{2,4,5,8} • <i>Alpha-chlordane, Gamma-chlordane, cis-nonachlor, trans-nonachlor</i> Dieldrin ^{2,4,5,6,8} Toxaphene ^{3,4,5,6,8} Mirex ^{3,4,5,6} • <i>Photomirex</i> Alpha-hexachlorocyclohexane Beta-hexachlorocyclohexane Delta-hexachlorocyclohexane Gamma-hexachlorocyclohexane	Historical use on crops, microcontaminant in dicofol Historical use on crops and for termite and ant control Historical use on crops, termite and moth control Historical use on crops, topical insecticide Historical use for fire ant control and flame retardant Agricultural and topical insecticides
Industrial Organochlorine compounds or byproducts	
PCBs ^{2,3,4,5,6,8} Dioxin (2,3,7,8-TCDD) ^{4,5,6} 1,4-Dichlorobenzene ^{4,5} Pentachlorobenzene ^{4,5} 1,2,3,4-Tetrachlorobenzene ^{4,5} 1,2,3,5-Tetrachlorobenzene ^{4,5} Pentachlorophenol ^{4,5} Hexachlorobenzene ^{4,5,8} 3,3'-Dichlorobenzidine ^{4,5} 4,4'-Methylenebis(2-chloroaniline) ^{4,5}	Transformers, hydraulic fluids, capacitors, heat transfer fluids, inks, casting waxes Combustion byproducts, contaminant in pentachlorophenol wood preservative, other chlorophenols and derivatives, including herbicides Mothballs, household deodorants, other biocides Chemical synthesis Chlor-alkali plants, wood preservatives Byproduct of chemical manufacturing, historical wood preservative and fungicide Plastic manufacturing, glues and adhesives, dyes and pigments for printing inks Plastics, adhesives
Polynuclear aromatic hydrocarbons (PAHs)^{4,5,8}	
<i>Anthracene, Benz(a)anthracene</i> <i>Benzo(a)pyrene, Benzo(b)fluoranthene</i> <i>Benzo(k)fluoranthene,</i> <i>Benzo(g,h,i)perylene</i> <i>Chrysene, Fluoranthene, Phenanthrene</i> <i>Indeno(123-cd)pyrene</i>	Coal, oil, gas, and coking byproducts, waste incineration, wood and tobacco smoke, and forest fires, engine exhaust, asphalt tars and tar products
Trace Metals	
Alkyl lead ^{4,5,6} Cadmium ^{4,5} Copper ⁶ Lead ⁶ Zinc ⁶ <i>Mercury^{3,4,5,6}</i> Tributyl Tin	Leaded gasoline Batteries, pigments, metal coatings, plastics, mining, coal burning metal alloys, rubber, dye, steel production Same as cadmium, plus plumbing and wiring Same as cadmium, plus solder Same as cadmium, plus roofing Batteries, coal burning, chlor-alkali plants, paints, switches, light bulbs, dental material, medical equipment, ore refining Antifouling paint, mildewcide, plastic stabilizer
Current-use herbicides⁷	
Atrazine, Cyanazine, Alachlor, Metolachlor	Agricultural herbicides
Other Contaminants	
Total phosphorus, Nitrate-nitrogen Fecal Coliform, <i>Escherichia coli</i> <i>Total suspended sediments</i>	Fertilizers and sewage Sewage and animal waste Soil erosion

¹Contaminants indented are degradation products; those shown in italics have been identified as chemicals of concern

² Lake Erie Chemicals of Concern identified by Lake Erie LaMP in 1994

³Great Lakes Initiative Bioaccumulative Chemical of Concern (BCC)

⁴COA-Tier1 or Tier 2 contaminant

⁵Binational Toxic Strategy contaminant

⁶Contaminant identified by the IJC or in Remedial Action Plans

⁷U.S. EPA

⁸Canadian Toxic Substance Management Policy – Track 1

The Sources and Loads Subcommittee also compiled a second, more comprehensive list of pollutants and their degradation products designated by a variety of agency programs as being pollutants of concern within the Lake Erie basin (Table 5.2). This expanded list formed the basis for evaluation of information on all the pollutants of concern in Lake Erie to determine the suitability of the data for estimating loads and whether there are ongoing sources or pathways of contamination to the Lake Erie ecosystem.

In 2000, the Subcommittee provided an overview of the results of the *Characterization of Data and Data Collection Programs for Assessing Pollutants of Concern in Lake Erie* (Painter et al., 2000) to the LaMP. Briefly, this study characterized the information available from both the U.S. and Canadian public sectors and research laboratories in digital databases, and assessed the suitability of these data for identifying sources and characterizing pollutant concentrations and loadings to Lake Erie.

In general, data for nutrients (phosphorus and nitrate-nitrogen), suspended sediment and atrazine (an in-use pesticide) were considered likely to be adequate for characterizing tributary and point source concentrations and loads to the lake. However, for the organochlorine compounds, PAHs and trace metals, the majority of the databases were considered to contain data of insufficient quality and quantity or to be not applicable to characterize tributary, lake, or point source concentrations or annual loads to Lake Erie within acceptable levels of uncertainty. The insufficiencies were due to a number of factors, including the past use of methods that do not meet current quality assurance and quality control specifications for sampling in the part per billion and part per trillion concentration ranges, at which many of these compounds are now known to persist in the environment.

Concentration data for aquatic bed sediments and fish tissue were determined to be less susceptible to the limitations of quality and quantity than the organochlorine, PAH and trace metal data reported for surface water. Although not suitable for computing loads, these data could provide a strong indication of the extent and severity of contamination in the Lake Erie basin, and could be used to help indicate important source areas.

The findings and recommendations made in the report have helped to guide the activities of the Subcommittee since that time. Because a binational commitment to virtually eliminate sources of persistent toxic substances has already been made, and given the relative inadequacy of existing data to compute loads for these pollutants, it was determined to be more productive to pursue methods other than the calculation of loadings to identify the major sources and pathways of critical pollutants in Lake Erie.

5.2 Integration of Basin-Wide Sediment Quality Data, 1990 – 2001 (U.S. and Canada)

The Sources and Loads Subcommittee is integrating available information from many jurisdictions in both the United States and Canada about the pollutants of concern and the Lake Erie critical pollutants. Ambient environmental information including sediment quality data, tissue residue levels in aquatic biota and other information sources, are being compiled into the Lake Erie Information Management System (LIMS) together with information about potential contaminant sources such as municipal and industrial discharge data. The integration of information is facilitating management discussions on possible sources of these pollutants in the Lake Erie basin.

As a priority activity, the Sources and Loads Subcommittee has integrated sediment quality data on a binational basis. Sediments are an appropriate medium for contaminant analysis, since many of the contaminants of concern preferentially adsorb to sediment. In addition, a great deal of sediment quality data already exists across the basin. As primary depositional material, sediments not only implicate potential sources of contamination, but they also are the substrate by which food web uptake begins. In the near future, the LaMP Sources and Loads Subcommittee will perform comparisons between contaminants found in sediments and those found in fish tissue.

Integration of the available information identified data gaps, and several studies were initiated to ensure a more comprehensive information base. For example, when recent information on the spatial distribution of open lake sediment pollutant concentrations was

required for the project described above, Environment Canada and Ohio EPA collaborated on a study that provided open lake pollutant concentrations in surficial sediments for many historical and emerging chemicals of concern. The 1997/98 survey conducted by Environment Canada and Ohio EPA not only provided valuable information on the open lake spatial distribution of contaminants, but because an earlier 1971 Environment Canada survey had been conducted, a retrospective analysis of the trends over time was also possible (Painter et al. 2001). Encouragingly, PCB concentrations have declined lakewide. Concentrations are one third of what they were 30 years ago. Mercury concentrations have also similarly declined.

The sediment distribution of the two LaMP critical pollutants, PCBs and mercury, as shown in Figures 5.1 and 5.2, were originally presented in the 2002 LaMP report. These figures represent an evaluation of PCBs and mercury in bed-sediments as compared to predetermined aquatic biological effect levels called threshold effect levels (TEL) and probable effect levels (PEL) after Smith, et al. (1996).

Dioxin concentrations in surficial sediments of Lake Erie were unavailable prior to the study conducted by Environment Canada and Ohio EPA. The Canadian probable effect level (21.5 pg/g TEQ) (CCME, 1999) was exceeded at 40% of the sites, all in the western and south-central basins of the lake (Figure 5.3).

In addition, information was collected on the following pollutants: chlordane, a former-use pesticide typically used for controlling insects in the home; polynuclear aromatic hydrocarbons (PAHs), a complex series of compounds resulting from the incomplete combustion of fossil fuels such as coal, gasoline, fuel oils, and tar, but also from the combustion of wood; and lead, having historical uses in gasoline and now found in oil and coal combustion, metal refining and fabrication, and waste incineration. Concentrations of these pollutants are presented in Figures 5.4 to 5.6 as compared to biological effect levels described by Ingersoll et al. (2000) and MacDonald et al. (2000), represented as Threshold Effect Concentrations (TEC) and Probable Effect Concentrations (PEC).

Chlordane is found above the PEC (17.6 µg/kg) in and downstream of all major urban areas in the drainage area. This apparently has a slight impact on the western basin and south shore of Lake Erie, where exceedences of the TEC (3.24 µg/kg) are observed regularly. Less frequent are the occurrences of elevated chlordane above the PEC and TEC in bed-sediments along the north shore of Lake Erie (Figure 5.4).

Similar to chlordane, total PAHs (the sum of individual PAH compounds) are also found above the PEC (22,800 µg/kg) in and around all major urban centers within the drainage area. However, total PAHs are also found at concentrations exceeding the PEC in smaller urban areas, owing to the widespread abundance and persistence of PAH compounds in the environment. As expected, some of the highest concentrations (greater than 10 and 100 times the PEC) are found in heavily industrialized centers, but a few highly contaminated areas are isolated from major urban centers (Figure 5.5). These point-source signatures are manifest in the open lake environment, where concentrations exceeding the TEC (1,610 µg/kg) are found frequently in the western basin, the central basin and along the entire south shore. Fewer exceedences of the TEC are observed along the north shore of Lake Erie.

Similarly to chlordane and total PAHs, lead is found above the PEC (128 mg/kg) primarily in urban and industrial areas, and its distribution in the open lake basins is greater in the west compared to the east (Figure 5.6). Concentrations along both the south and north shores exceed the TEC (35.8 mg/kg), but exceedences are found more frequently along the south shore.

Figure 5.1: Total PCBs in bed sediments

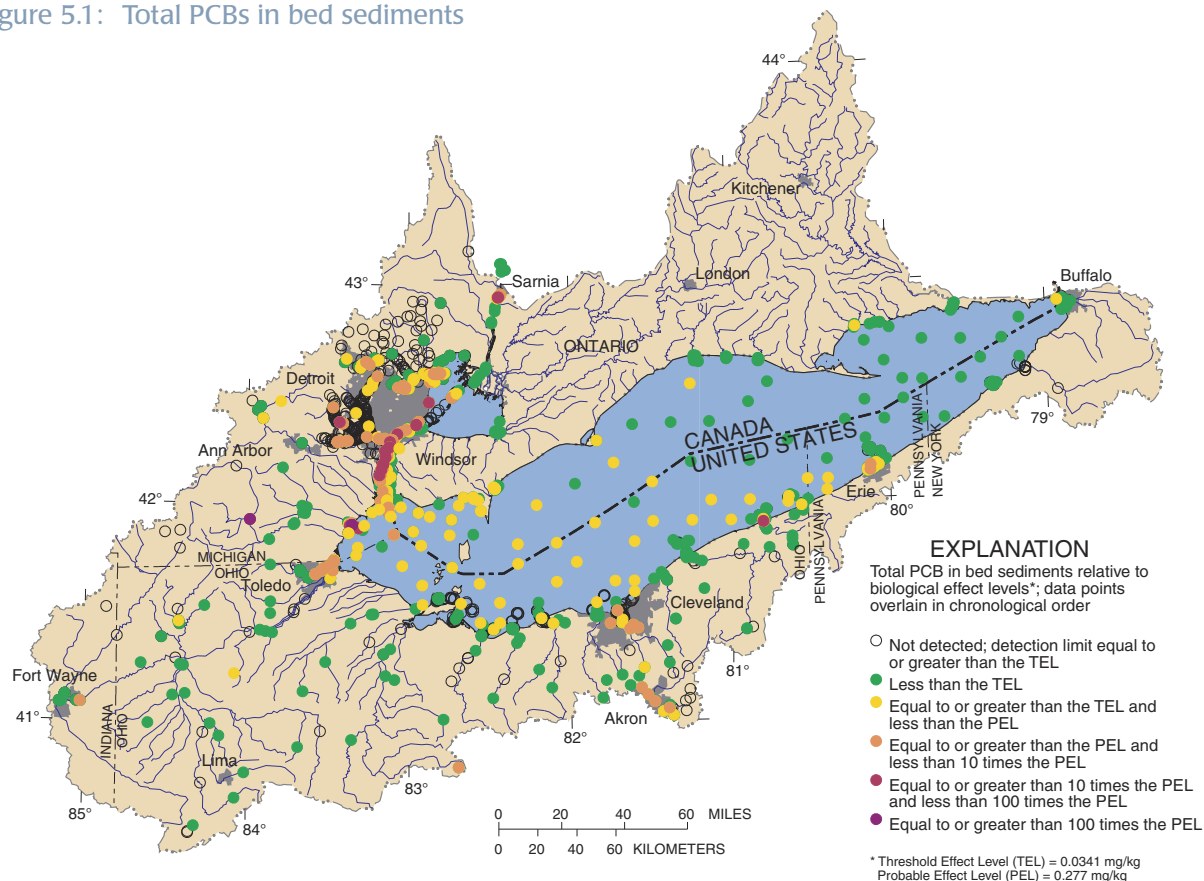


Figure 5.2: Total mercury in bed sediments

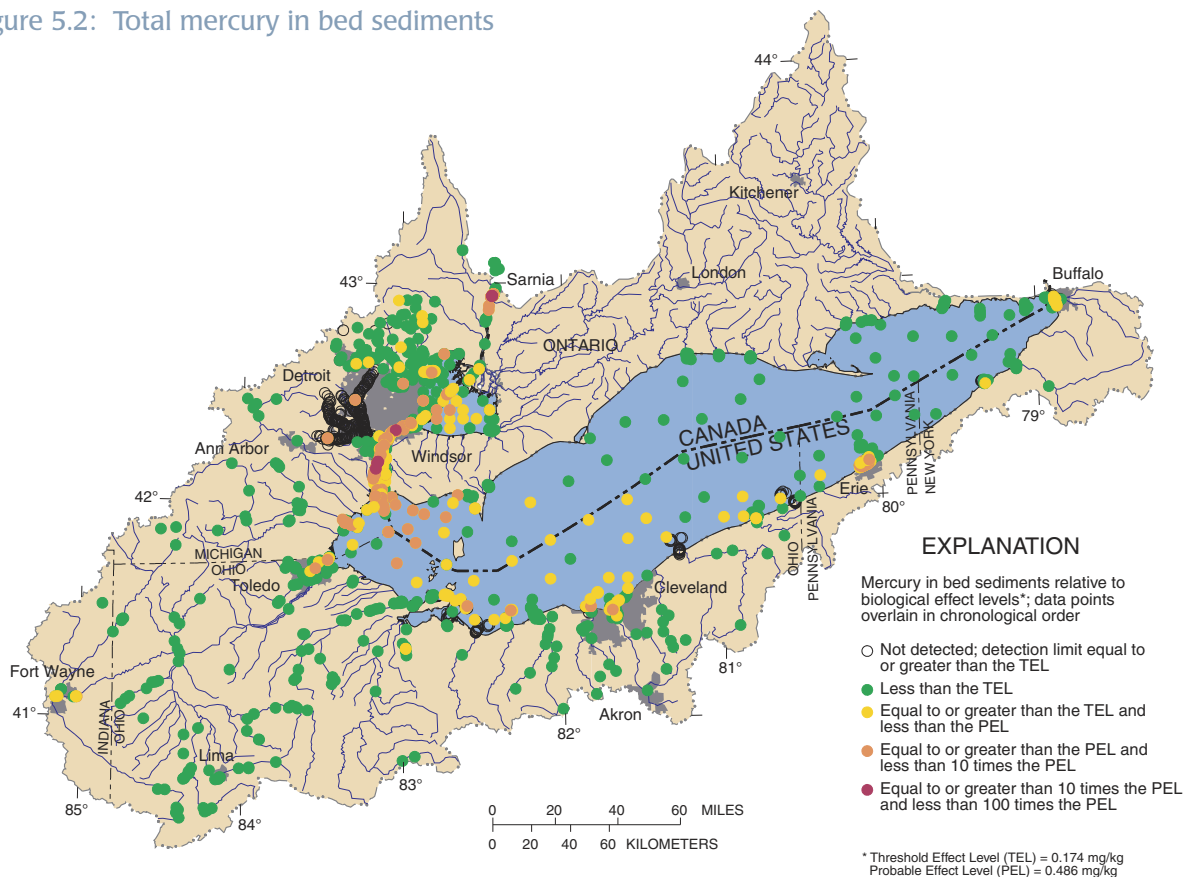


Figure 5.3: Surficial sediment concentration of dioxin (pg/g TEQ)

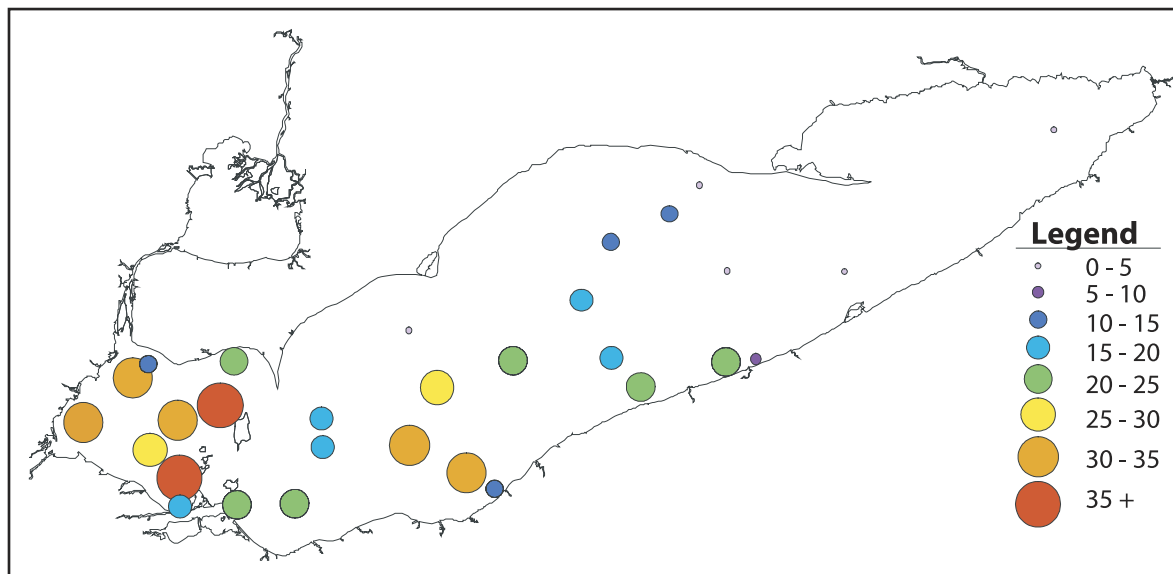


Figure 5.4: Total chlordanes in bed sediments of the Lake Erie - Lake St. Clair basin, 1990-2002

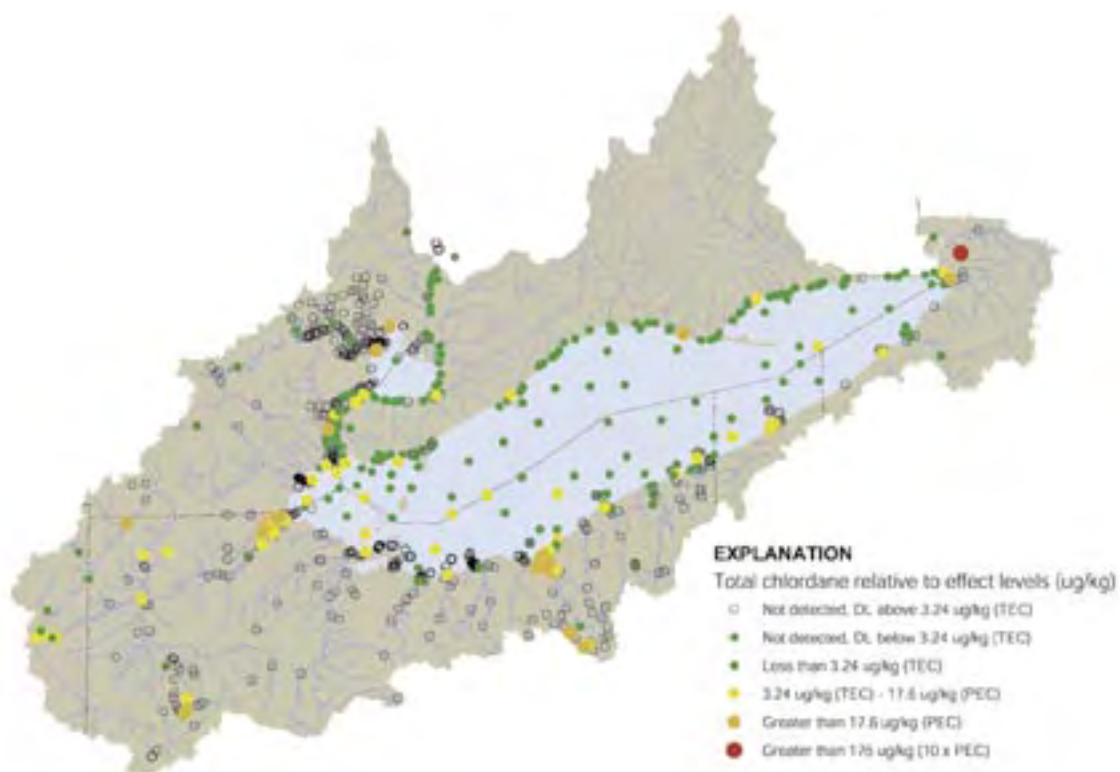


Figure 5.5: Total PAHs in bed sediments of the Lake Erie - Lake St. Clair basin, 1990-2002

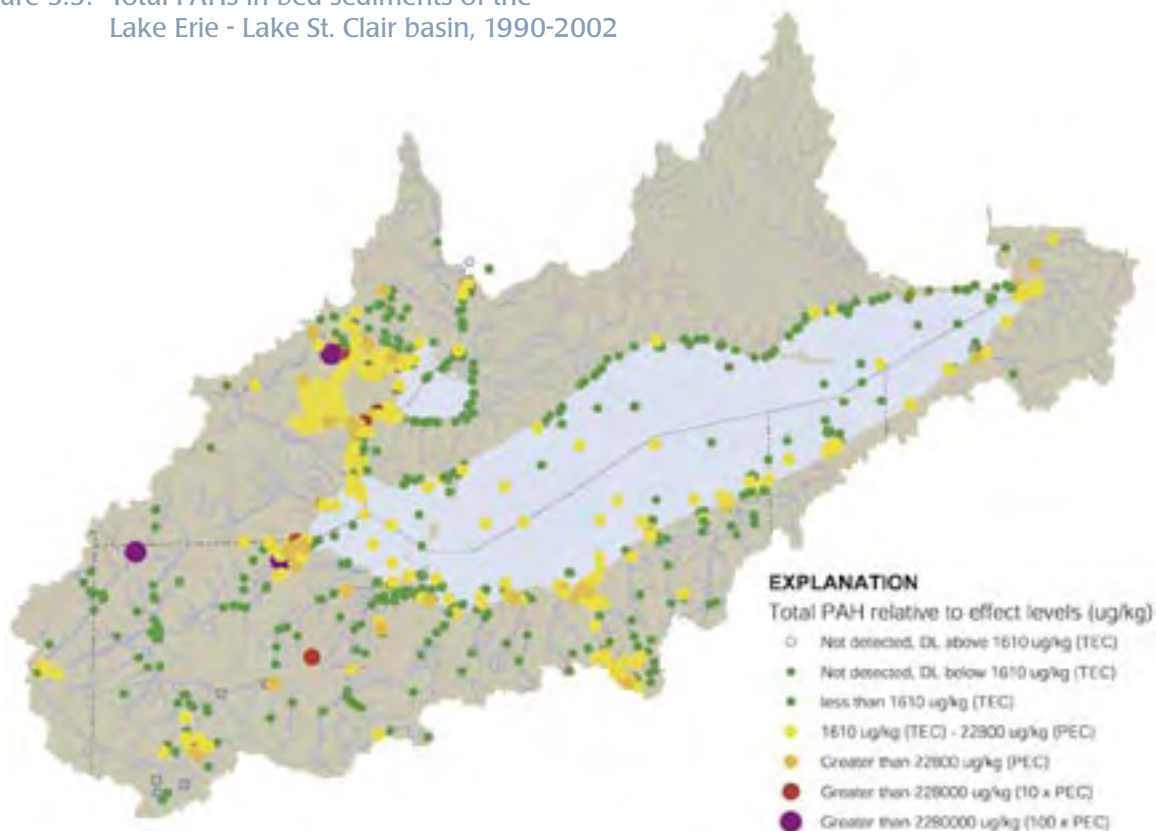
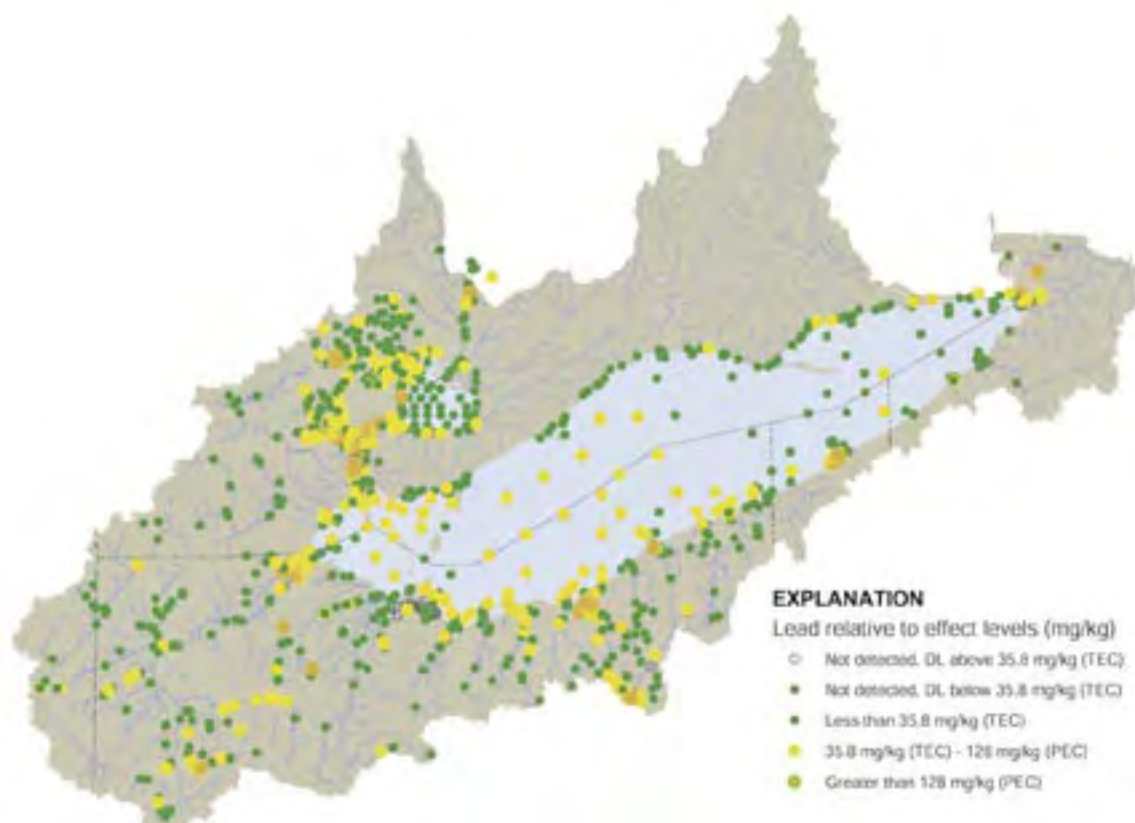


Figure 5.6: Lead in bed sediments of the Lake Erie - Lake St. Clair basin, 1990-2002



SMART (Sediment Management, Assessment and Remediation Team)

In an effort to organize the basin-wide assessment for the management and reduction of contaminated sediments, the Lake Erie LaMP Sources and Loads Subcommittee sponsored a meeting that convened in Presque Isle Bay State Park, Pennsylvania, in the summer of 2002. Representatives were from both Canada and the United States with national, state, and local interests. They included Environment Canada, Ontario Ministry of Environment, U.S. Environmental Protection Agency, U.S. Geological Survey, Michigan Department of Environmental Quality, Ohio Environmental Protection Agency, and Pennsylvania Department of Environmental Protection.

The opportunities for using a basin-wide sediment database from multiple sources mapped in a geographic information system (GIS) seem endless, however much of the discussion revolved around addressing a number of topics: 1) the completeness of the database, 2) the spatial distribution of different contaminants, 3) identifying key areas of the basin with apparent multiple contaminant issues, 4) determining if there are needs for new or additional monitoring, and 5) determining if there any known contaminated areas that are not being addressed at this time.

Key points made during the workshop with regards to management of contaminated sediments were that:

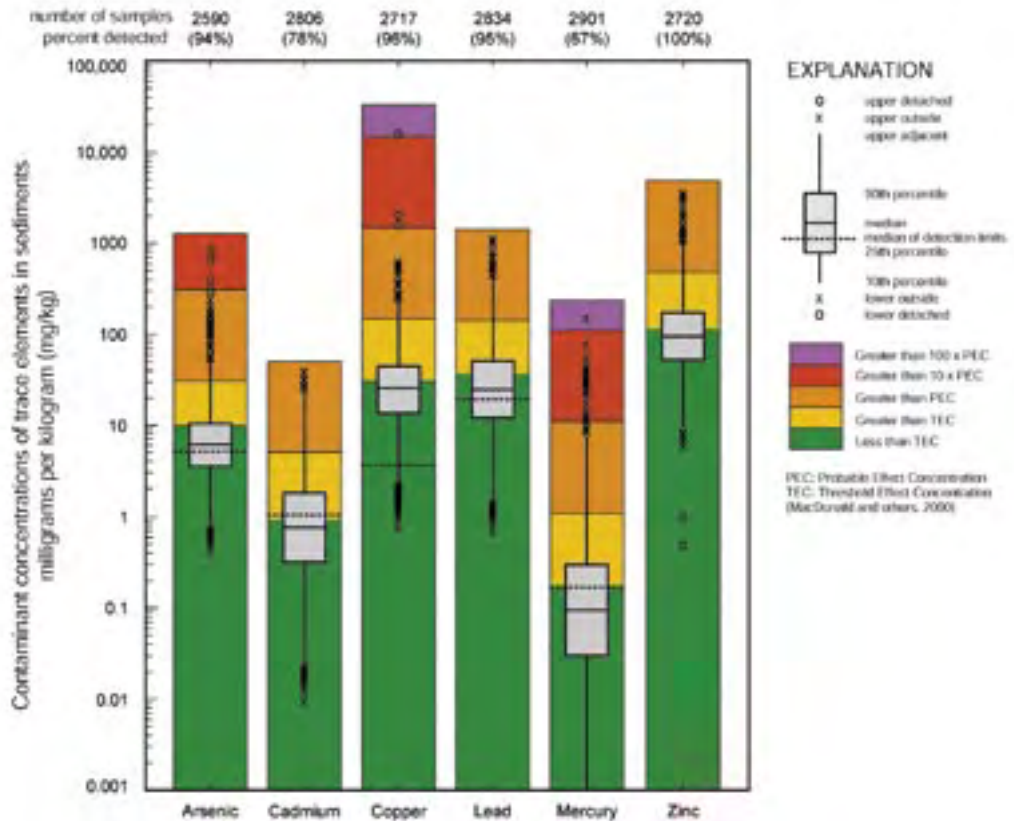
- Certain agencies have the programs and funding to clean up contaminated sediments, but lack an approved location to dispose of the sediments.
- The contamination quality typically left behind after dredging projects may still represent some of the most contaminated sites remaining in the basin. Sediment remediation efforts typically focus on highly contaminated hot-spots in well-defined zones, whereas sediment contamination in excess of biological sediment quality guidelines may be wide-spread. Moreover, criteria for sediment remediation (i.e., cleanup levels) are not as stringent as some sediment quality guidelines. To clean up to more stringent guidelines would be cost prohibitive, in many cases. However, the divergence between sediment cleanup guidelines and desired sediment quality must be addressed if we are to attain sediment quality that sets guidelines at contaminated sites in the Lake Erie basin.
- The apparent decreasing west to east gradient for many parameters in the open lake indicates that sources are primarily point sources into the system and not principally the result of atmospheric deposition.
- Controlling contaminant movement is not simple. Historically deposited contaminated sediments may be re-suspended and move downstream during storm events or may be disturbed by shipping activities.
- As point sources are identified and controlled, the role of non-point sources may become more important. Non-point sources such as contaminated soils and leaky landfills will be difficult to track, and their identification and control may represent a major challenge to further improvements in the open lake contaminant status.

5.2.1 Statistical Summaries of Contaminants in Bed Sediments

Concentrations of selected contaminants in bed sediments are summarized in Figures 5.7 to 5.9. The samples were collected during 1990 to 2003. These box plots represent both a statistical summary of the range of detected concentrations, as well as extrapolations of the non-detected samples (using the Adjusted Maximum Likelihood Estimator (AMLE) method for the interpretation of multiple samples with no detections, Helsel and Hirsch, 1993). The selected contaminants are depicted on a logarithmic scale relative to established biological effect levels: Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC), as developed by MacDonald et al. (2000). TEC and PEC values do not exist for mirex and hexachlorobenzene (HCB). Lowest Effect Levels (LEL) and Severe Effect Levels (SEL) (Persaud et al. 1993) were used instead.

Figure 5.7 shows a statistical summary of selected trace elements from the Lake Erie LaMP Pollutants of Concern Table 5.2, as well as arsenic. In each and every case, the median concentrations (50% of the results) are found to be below the TEC. This supports the understanding that high levels of trace element contamination are not systemic throughout

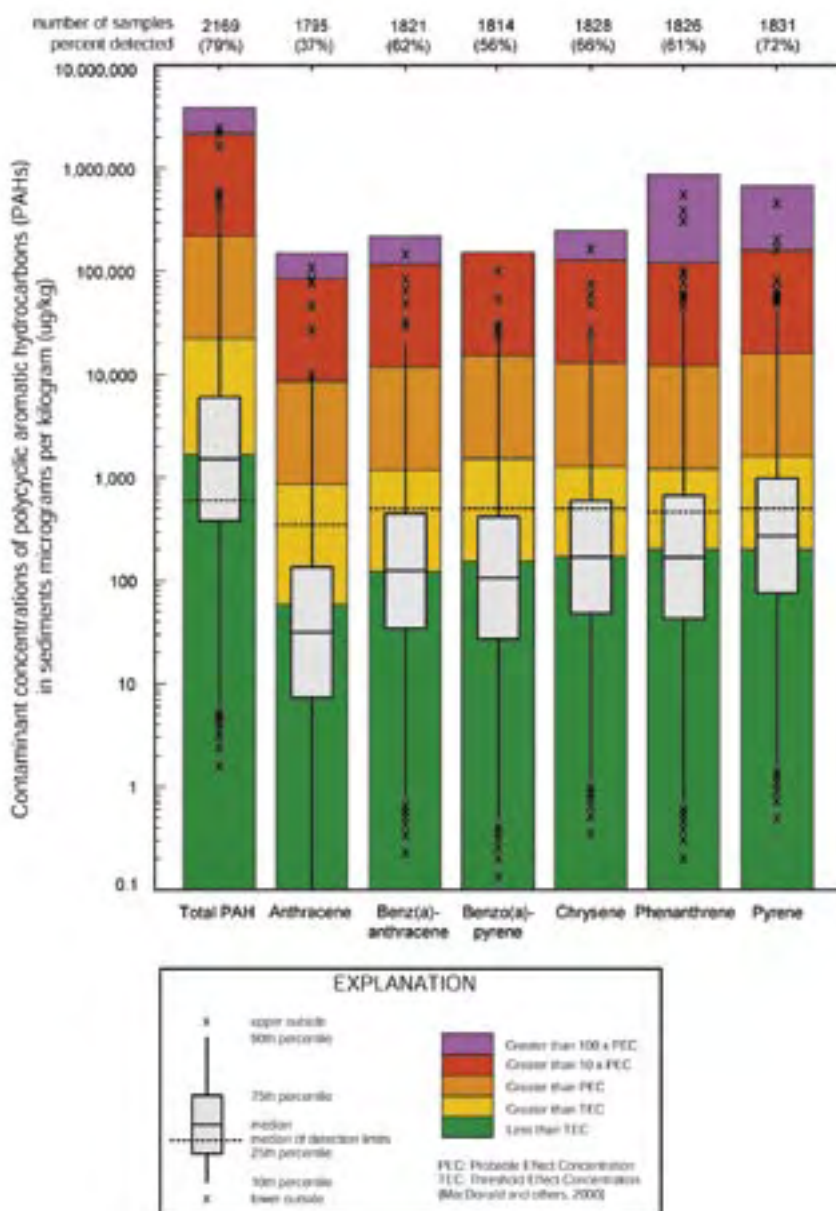
Figure 5.7: Summary statistics shown in boxplot format for trace element contaminants in bed sediments of the Lake Erie Basin, relative to biological effect levels. Data compiled from various provincial, state, local and federal agencies, 1990-2003.



the basin in either the tributaries or the open lake, but rather co-located with source areas such as urban-industrialized areas. Furthermore, for each contaminant, the top 25 percent of the sample results extend above the TEC, and the top 10 percent of each contaminant extends above the PEC. Percent detections range from 67 percent for mercury to 100 percent for zinc. Arsenic, copper and mercury all showed concentrations exceeding 10 times the PEC at discrete locations within the basin, while only copper and mercury were found to be exceeding the PEC by 100 times each at one location. The highest concentrations of trace elements, those exceeding the PEC, were found to be associated with, or downstream of, urban-industrialized areas such as: Buffalo, NY; Erie, PA; Cleveland, Akron, Lorain, Toledo, and Lima, OH; Monroe, Detroit, and Pontiac, MI; and Windsor and Sarnia, ON. For those samples with no detections, the median of detection limits were, for all contaminants except cadmium, at or below the TEC.

Total PAH represents either a lab measure result or a database calculated result of U.S.EPA's 16 most commonly measured PAHs. A statistical summary of total PAH and selected individual PAH compounds is shown in a series of boxplots represented in Figure 5.8. Frequency of detection ranged from 37 percent for anthracene to 79 percent for total PAH. More than half of the samples for anthracene, benzo(a)pyrene, chrysene, phenanthrene, and total PAH were found to be below the TEC, but for benz(a)anthracene and pyrene, more than half the samples were found to be above the TEC. Each contaminant and total PAH had greater than 25 percent of the results above the TEC, and the top ten percent of the samples were found to be above levels ten times greater than the PEC. All contaminants had at least one sample concentration exceeding 100 times the PEC, except for benzo(a)pyrene. Overall, individual PAH contaminants showed relatively the same statistical distribution pattern, while concentrations of total PAH were found to be at least one order of magnitude above individual contaminants. Both findings support the fact that multiple contaminants of PAHs are usually found together when a given source is present. Much like trace elements, the

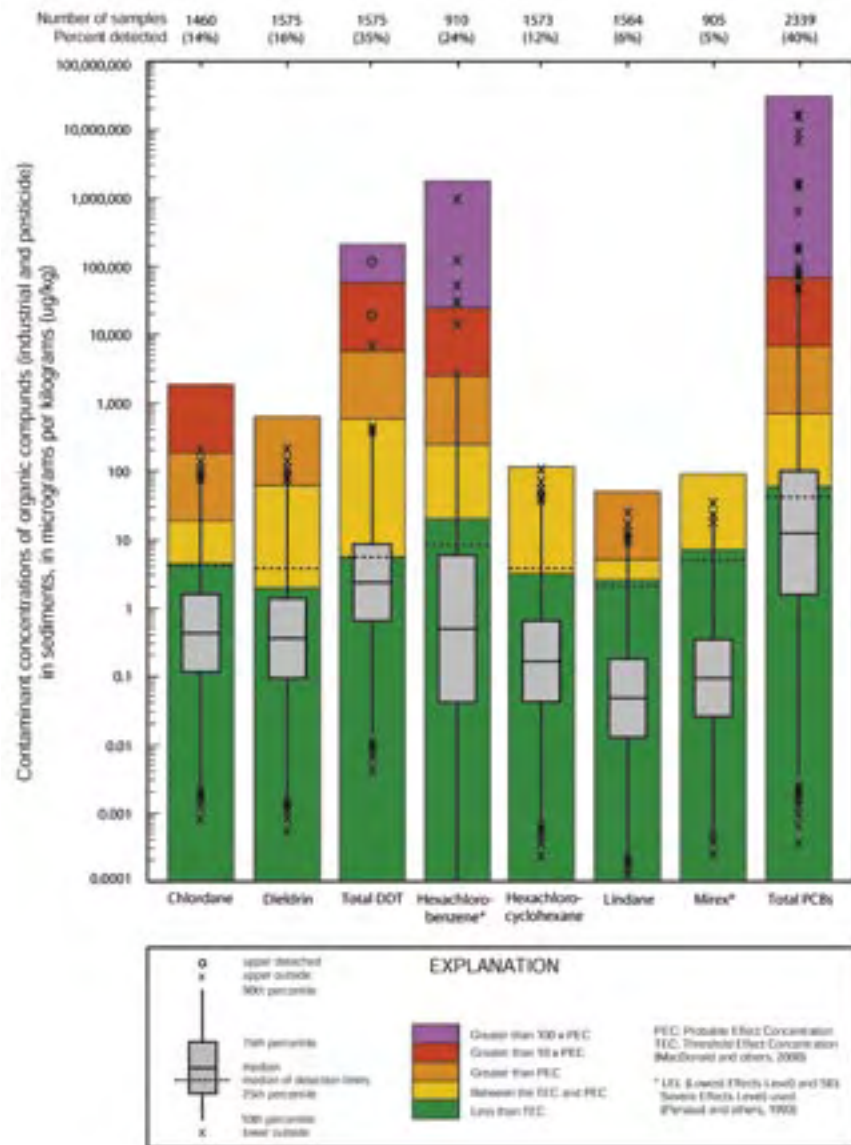
Figure 5.8: Summary statistics shown in boxplot format for PAH contaminants in bed sediments of the Lake Erie Basin, relative to biological effect levels. Data compiled from various provincial, state, local and federal agencies, 1990-2003.



high concentrations of PAH compounds were found to be near or downstream of urban-industrialized areas such as: Akron, Cleveland, Lorain, and Toledo, OH; Detroit and Pontiac, MI; and Sarnia, ON. However, high amounts of PAH contaminants in streams and inland lake sediments were also seen in rural communities in northwest Ohio where concentrations have been linked to creosote production and petroleum processing and refining.

Despite being banned from production almost 30 years ago, various manmade organochlorine contaminants are still persistent in the environment. They are still detected in bed sediments, and continue to bioaccumulate up through the food web. Figure 5.9 shows the statistical distribution of various organochlorine pesticides (DDT, dieldrin, mirex, lindane, chlordane, hexachlorocyclohexane, hexachlorobenzene) along with total PCBs, that were sampled from 1990 to 2003. The range of detected concentrations for the organochlorines is quite large, extending over 12 orders of magnitude from the lowest detection limit to the highest measured concentrations of total PCBs. Frequency of detection for organochlorine compounds was generally much lower than detections of trace elements or PAHs. Detection

Figure 5.9: Summary statistics shown in boxplot format for industrial and pesticide contaminants in bed sediments of the Lake Erie Basin, relative to biological effect levels. Data compiled from various provincial, state, local and federal agencies, 1990-2003.



frequencies for pesticides ranged from 35 percent for DDT to 5 percent for mirex. PCBs were detected 40 percent of the time.

Given the lower frequency of detection and the integration of the non-detections into the summary statistics, it is encouraging to see that the median concentration of organic compounds never exceeded the TEC or LEL. Moreover, only DDT and PCBs had greater than 25 percent of the samples above the TEC. Chlordane, dieldrin, and lindane (HCB-g) all had greater than 10 percent of their results above the PEC, while more than 10 percent of the samples from hexachlorobenzene (HCB-a,b,d,g) and total PCBs extended above 10 times the PEC. Individual samples of DDTs, hexachlorobenzene and total PCBs were found to be greater than 100 times the PEC.

The highest concentrations of organochlorine pesticides in stream and lake-bed sediments follow a pattern indicative of their historic use in residential, industrial and agricultural settings, and were found near or downstream of: Buffalo, NY; Erie, PA; Cleveland, Lorain, Lima, and Defiance, OH; Dundee, Monroe, and Detroit, MI; and Sarnia, ON. In all the organochlorine compounds, the median of the detection limits extended above the median

measured concentration, and in the case of dieldrin and hexachlorocyclohexane, the median of the detection limits extended above the TEC or LEL. For all contaminants, when detection limits extend above the lower biological effects levels (TEC or LEL) they become too great to help with any interpretation of the sediments' effects on biological susceptibility.

A detailed summary of the bed sediment data analyzed for use in the LaMP 2006 Report, along with related fish tissue and source data, will be published by USGS in 2007.

5.3 Screening-Level Survey of Tributaries to the Lower Great Lakes (Canada)

Environment Canada, Ontario Region, has conducted a screening-level survey of sediment quality in tributaries to the lower Great Lakes. In 2001, approximately 100 Canadian tributaries to the St. Clair River, Lake St. Clair, the Detroit River and Lake Erie were sampled. Since that time, follow-up investigations have been conducted in selected Lake Erie watersheds. Virtually every tributary draining Ontario watersheds to the lower Great Lakes and their interconnecting channels are being sampled in this program.

To achieve the program objectives, a single, composite sediment sample is obtained from each tributary in a manner that maximizes the probability of detecting contaminants, if they exist, at the site. The targeted substances are relatively insoluble in water (i.e., hydrophobic) and, if present, are typically found at higher concentrations in sediments than in water. The sampling protocol is based upon the *Guidelines for Collecting and Processing Samples of Stream Bed Sediment for Analysis of Trace Elements and Organic Contaminants*, developed by the United States Geological Survey (USGS) for the U.S. National Water-Quality Assessment Program (NAWQA) (Shelton and Capel 1994). In the NAWQA program, downstream locations in watersheds are selected to provide a coarse-scale network of sites. At these integrator sites, large-scale problems that may not be detected in smaller basins have a reasonable chance of being detected.

The sediment samples are submitted for analysis of organochlorine compounds, PAHs, metals, total organic carbon and particle size distribution. Selected samples are also being screened for additional parameters such as dioxins and furans, polychlorinated naphthalenes, polybrominated diphenyl ethers, in-use pesticides and other parameters of emerging concern, as resources permit.

The results of these surveys provide information about recently deposited sediment quality, and can be used to help identify if Canadian watersheds are sources of pollutants to the Great Lakes. The results are also used to prioritize sites for any subsequent follow-up work. An internal Environment Canada data report entitled *Sediment Quality in Canadian Lake Erie Tributaries – A Screening Level Survey* (Dove et al., 2002) has been shared with other environmental agencies, and confirmatory and/or follow-up work has already been initiated at all tributaries in the Lake Erie basin that showed elevated concentrations of either of the two Lake Erie critical pollutants, PCBs and mercury.



Photo: Environment Canada

5.4 Source Track-Down Project (Canada)

As part of a commitment to virtually eliminate the releases of persistent, bioaccumulative and toxic substances to the Great Lakes, the Ontario Ministry of the Environment (MOE) and Environment Canada (EC) have partnered to track down possible active sources of PCBs in Great Lakes watersheds. To date, three pilot projects have been undertaken in the Lake Ontario basin. Several objectives were intended for these pilot projects that are of interest to the Lake Erie LaMP:

1. To determine if such track-down projects are effective means of reducing local sources of PCBs;
2. To assess the effectiveness of various investigative tools;
3. To develop appropriate project design and methodologies, and;
4. To develop a guidance framework for future track-down projects.

The project partners have been working on developing the tools to help guide the selection, initiation and conduct of future track-down projects. It is anticipated that similar track-down projects will be initiated in Lake Erie. The initial focus will be to track down sources to tributaries that result in exceedences of environmental criteria near the point of discharge to Lake Erie. Projects would be initiated on a priority basis, with consideration of all available information to determine whether a track-down project would be warranted at a particular site.

5.5 Mercury and PCB Reduction Initiatives

The Great Lakes Binational Toxics Strategy (GLBTS) is the principle mechanism used by the LaMP to address pollution prevention and reduction initiatives for LaMP identified critical pollutants. Specifically, the GLBTS seeks to achieve reductions of use and/or release of various persistent bioaccumulative toxic substances, including mercury and PCBs, through voluntary agreements, projects and information sharing about cost-effective reduction opportunities for state, provincial and local governments, industry, and non-government organizations. This report provides a very brief overview of mercury and PCB activities. The GLBTS 2003 Progress Report (available online at www.binational.net) provides more detailed information.

National and International Activities

As with all the Great Lakes, Lake Erie receives deposition of airborne toxics from both distant and local sources. National and international programs have an important role in protecting Lake Erie from inputs of critical pollutants by reducing releases both within the basin and, in the case of pollutants that are atmospherically transported long distances, into the basin.

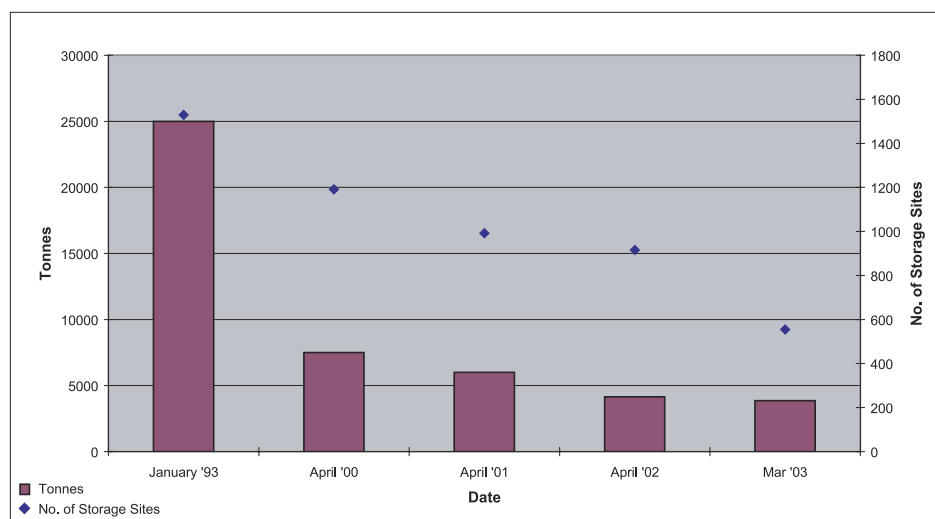
The United States and Canada have both signed the Stockholm convention on Persistent Organic Pollutants, which restricts the global production and use of twelve chemicals, including PCBs, dioxin, toxaphene, dieldrin, DDT, chlordane, and hexachlorobenzene (HCB). Canada has ratified this treaty and, in the United States the Senate Public Works and Environment Committee has recommended ratification. In addition, both nations are participating in the Mercury Programme of the United Nations Environment Programme, which has urged all countries to adopt goals and take actions, as appropriate, to identify populations at risk and to reduce human-generated releases of mercury.

At the national level, both countries have implemented actions to reduce air emissions of mercury, PCB, and other contaminants.

PCB Reduction Progress

The long-range transport of PCBs is a significant portion of the loadings experienced within the Lake Erie Basin. While the GLBTS 2003 Progress Report doesn't break out progress specific to the Lake Erie Basin, the report provides the broader context for loading reductions for Lake Erie.

Figure 5.10: High level PCBs and number of storage sites in Ontario



As of March 2003, approximately 85 percent of high-level PCB wastes in Canada had been destroyed, up from approximately 40 percent in spring 1998 when work in support of the GLBTS commenced. From April 2001 to March 2003, approximately 1,300 tonnes of high-level PCBs were destroyed (Figure 5.10), and as of April 2003, approximately 983 storage sites (both federal and private) were PCB-free (no PCBs in use or in storage), with about 555 sites still remaining.

Rates of PCB phase-out have declined in recent years because remaining PCB equipment is difficult or expensive to replace and the fate of the Canadian PCB incinerator in Swan Hills, Alberta, is uncertain. However, the Canadian government is planning to regulate PCB phase-out dates (see Table 5.3 for proposed PCB regulations). Awareness among owners continues to increase due to continuing PCB outreach, the PCB Phase-Out Awards Program (Canada), sector mail-out of information, and voluntary commitment letters. Newer facilities and options are now available in Ontario for PCB decontamination and destruction, in addition to the Alberta Swan Hills incinerator. Owners of large quantities of PCBs have been able to incorporate PCB phase-out and destruction activities into multi-year operating plans, but smaller businesses have difficulty absorbing a large capital expense in any one fiscal year.

The priority sectors in Ontario that still have a considerable amount of high-level PCBs in use include: iron/steel, governments, and mining/smelting. In addition, schools, care facilities, and food processing are priority sectors as sensitive areas that still have high-level PCBs in use. These sectors need to be targeted for PCB decommissioning. Sectors in Ontario that need to be targeted for destruction of high-level PCBs in storage include the provincial and municipal governments, iron & steel production, and the forestry/pulp and paper industry.

According to annual reports submitted to U.S. EPA, the estimated amount of PCB transformers and capacitors remaining in the U.S. at the beginning of 2001 is less than 129,000 PCB transformers and less than 1,332,000 PCB capacitors. The reports do not include PCB transformers that have been reclassified or some capacitors that may be on the reports under the category of PCB article containers. The 1999 PCB Transformer Registration Database shows that there are approximately 20,000 PCB transformers currently registered and in-use in the U.S., but the actual number remaining in use is likely higher. Nonetheless, reductions of PCB transformers and capacitors continue to occur. U.S. EPA continues to evaluate ways to try to better quantify the data and help track progress toward meeting the U.S. challenge.

Current Focus of PCB Reduction Efforts

The GLBTS PCB Workgroup plans to continue its core activities, including the following:

PCB Reduction Commitments:

The Workgroup will continue seeking commitments to reduce PCBs through PCB reduction commitment letters and other PCB phase-out efforts.

Outreach/Sharing Information:

The Workgroup will continue to develop, distribute, and post on the Workgroup website, information which can facilitate and promote, as applicable, the identification and removal of PCB equipment. These include: photographs of electrical equipment; fact sheets; case studies that identify reasons companies remove PCBs; and a standard presentation of the PCB Workgroup's challenges and activities. The Workgroup will also continue to consider incentives for removing PCB equipment.

ISO 14000 and PCBs:

The PCB Workgroup has decided to lobby the ISO (International Standards Organization) to include PCBs as a specific hazardous material to be managed and eliminated. If the ISO were to include PCBs as a targeted substance, it would encourage applicants for ISO status to plan for the elimination of their PCBs.

Property and Liability Insurance and PCBs:

After questions and discussion at the May 2003 GLBTS Stakeholder Forum, the PCB Workgroup decided to investigate ways that insurance companies handle PCBs as an insurance risk. If insurance companies see PCBs as an "additional risk" above and beyond other hazardous substances, then it would be an advantage to PCB owners to eliminate their PCBs and reduce their risk ratings. U.S. EPA is looking into the potential for insurance to be used as an incentive for companies to remove PCBs.



Photo: U.S. EPA Great Lakes National Program Office

Table 5.3: PCB Reduction Plan Activities Update 2004

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
Pollution Reduction		
Work with automotive, iron and steel sector and electrical facilities in the Lake Erie basin to establish voluntary commitments to reduce the use, discharge or emissions of PCBs.	<p>Canada: (reductions noted below occurred in whole or in part in the Lake Erie Basin)</p> <p>Steel Sector:</p> <ul style="list-style-type: none"> Stelco achieved a 91 percent reduction of PCBs in storage and 41 percent reduction of in PCBs in service; The steel sector continues to work toward a solution to the large amount of PCBs in use transformers and capacitors. <p>Automotive:</p> <ul style="list-style-type: none"> The Canadian automotive industry destroyed 4,359 kgs and 133,495 litres of high-level PCBs across Ontario; Daimler-Chrysler, Canada, removed all high-level PCBs from transformers and capacitors and sent them to the Swan Hills PCB-incineration facility for destruction. <p>Utilities:</p> <ul style="list-style-type: none"> 42 electrical utilities submitted voluntary commitment letters to Environment Canada; A number of small- to medium-sized utilities in Ontario achieved 90 percent or better high-level PCB reduction targets; Hydro One has eliminated all high-level PCBs in its network; Canadian Niagara Power has eliminated all high-level PCBs from its Niagara area network; Festival Hydro (Stratford, Ont.) has eliminated all high-level PCBs; <p>Others:</p> <ul style="list-style-type: none"> Canadian Petroleum Producers Association and its members eliminated 90 percent of PCBs; City of Windsor and Essex County sent 65,000 kgs of PCB-contaminated materials to Swan Hills for destruction; Public Works and Government Services Canada has implemented an aggressive PCB phase-out program and has eliminated over 90 percent of their PCBs across Ontario; Conestoga College and Wilfrid Laurier University have eliminated all high-level PCBs from their inventories; The Thames Valley District School Board, Coca-Cola (Chatham), and Frito Lay (Cambridge) are all PCB-free. <p>U.S.: U.S. EPA began to finalize information for the nation wide outreach campaign on phasing out PCB equipment and investigated the use of a hotline number as the point of contact. In addition, in 2003, U.S. EPA funded an expansion of the outreach and PCB phase-out solicitation campaign that will enable additional facilities to be reached and provide for additional follow-up.</p>	EC and U.S. EPA
Coordinate LaMP and GLBTS efforts with all related partners in order to produce a cohesive, unified program to address PCBs in the Great Lakes.	Ongoing	EC and U.S. EPA
U.S. EPA Superfund commits to completing the remedies for Springfield Township Dump (MI); G&H Landfill (MI); Metamora (MI); and Fields Brook (OH) by the end of 2002.	<ul style="list-style-type: none"> Springfield Township Dump– Construction of remediation systems complete, including treatment and/or removal of 12,000 cy of sediment. Operation and maintenance is expected for the next 4 years. G&H Landfill – Construction of onsite remedial technology (landfill cap and slurry wall) complete, wetlands restored, with groundwater extraction ongoing for at least 30 years. Metamora – COMPLETE – Landfill cap constructed to contain 20,000 cy of sediment. Fields Brook – The cleanup of Fields Brook sediment and floodplain soils is complete. 52,369 cy of sediment were removed. O&M at the on site landfill and monitoring of the brook and floodplain will continue. Remediation is also complete at the six separate source control operable units. NRDA restoration underway. 	U.S. EPA

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
Formalize the PCB Phasedown Program pilot project with the major utilities in the Great Lakes basin. Program is designed to encourage the utilities to phase out PCB equipment.	U.S. EPA Region 5 received comments from industry representatives on components of the PCB Phasedown Program that may improve participation in the program. The Region is evaluating changing the components to address the comments.	U.S. EPA
Identify federally owned PCBs in the Lake Erie basin and seek their removal by the departments or agencies that own the PCBs.	Canada: Federal PCB database complete. Database is read-only and is limited to those with an approved login account. U.S.: As the study on the costs of the use and removal or replacement of PCB equipment continued, additional approaches to work with federal departments or agencies on removing PCB equipment they owned were pursued. U.S.EPA has begun to contact some of the owners to discuss PCB reduction challenges and requirements to register PCB transformers with U.S.EPA.	EC U.S. EPA
Organize small PCB owner workshops in the Lake Erie basin to exchange information on PCB management, decommissioning and destruction.	Information packages distributed in Sept. 2001 included PCB Owner Outreach Brochure, GLBTS-PCB Workgroup Activity Regional Update, and fact sheet on Ontario PCB In Use Inventory survey and a map showing PCB quantity and location in the Lake Erie basin.	EC and MOE
Encourage PCB owners to destroy PCBs in use or storage.	<ul style="list-style-type: none"> • PCB phase out commitment letters have been received from Ontario Power Generation to phase out and destroy approximately 81% of their high level PCB by 2001 and 100% by 2015. • PCB phase out commitment letter requests have been sent to the Council of Great Lakes Industry trade associations including: Aluminum Association of Canada and the Canadian Petroleum Products Institute. • A survey of over 2,000 PCB equipment owners was completed in 2002 in order to track de-commissioning progress and obtain commitments for phase-out. • A PCB Phase-Out Award program was initiated to give recognition to facilities that have conducted phase-outs. Environment Canada is also developing case studies for those that receive an award, in order to promote phase-outs and provide examples of beneficial factors considered when companies decide to remove PCBs. • Environment Canada has developed a GLBTS PCB Newsletter that will be used to promote the PCB elimination and award programs. The purpose of the newsletter is to summarize information about the GLBTS, PCBs as an environmental hazard, the Phase-Out Awards Program, and other issues in an eye-catching, simplified format. 	EC
Information		
Finalize the PCB Sources and Regulations Background Report.	COMPLETE. The report is available at www.epa.gov/glnpo/bns/pcb/index.html	EC and U.S. EPA
Finalize the PCB Options Paper under the GLBTS that identifies options that can be undertaken to reduce PCBs in the environment.	COMPLETE. The report is available at www.epa.gov/glnpo/bns/pcb/index.html	EC and U.S. EPA

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
Report on an annual basis the status of sediment remediation at priority sites within the Lake Erie basin.	COMPLETE for priority sites within Areas of Concern see Great Lakes Binational Toxics Strategy Annual Report at www.binational.net	EC and U.S. EPA
Regulation		
	<p>Canada: A notice with respect to PCBs in Automotive Shredder Residue was published in Gazette I on July 7, 2001 for facilities that generated residue contaminated with PCBs during 1998 – 2000. Four Environment Canada PCB regulations are being amended and targeted for Canada Gazette publication in 2004. These regulations are:</p> <ol style="list-style-type: none"> 1) The Chlorobiphenyl Regulations (1977), 2) The Storage of PCB Material Regulations (1992), 3) PCB Waste Export Regulations (1996), and 4) Federal Mobile PCB Treatment and Destruction Regulations. <p>Environment Canada is currently drafting revisions to the Chlorobiphenyl Regulations and Storage of PCB Materials Regulations under the Canadian Environmental Protection Act. The most significant revisions to the regulations will be the imposition of strict phase-out dates for certain categories of PCBs. Specifically, the following dates are proposed:</p> <ul style="list-style-type: none"> • Phase-out of most high-level (>500 ppm) PCBs in-service by the end of 2007, • Phase-out of most low-level (50-500 ppm) PCBs in-service by 2014, • Phase-out of all PCBs in storage by the end of 2009 and allow in-service PCBs to be transferred to storage for one year or less, • Phase-out of most high-level and low-level PCBs from sensitive locations within three years of the proposed regulations coming into force, • Decontamination of all out-of-service liquids containing PCBs to less than 2 ppm (previously liquids and solids up to 50 ppm could be re-used, recycled, or disposed in a landfill). <p>Revisions to the Federal Mobile PCB Treatment and Destruction regulations will see the strengthening of emissions release provisions, mainly to bring the federal regulations in line with existing provincial requirements. Extensive public consultation was conducted, and the revised regulations should be published in the Canada Gazette in early 2004. More information and updates can be found on the Environment Canada website (http://www.ec.gc.ca/pcb/).</p> <p>U.S.: In the Federal Register of July 30, 2003, a final rule was published with an effective date of September 9, 2003, that clarified how used oil that is contaminated with PCBs is regulated, as follows:</p> <ul style="list-style-type: none"> • Used oil containing PCBs at concentrations of 50 ppm or greater is subject to Federal PCB regulations. Dilution may not be employed to avoid this regulation, unless otherwise specifically provided for by the RCRA or Federal PCB regulations. • Used oil containing PCBs at concentrations less than 50 ppm is subject to the RCRA used oil management standards, unless it has been diluted (from 50 ppm or greater), in which case it is treated as having 50 ppm or greater PCBs. 	EC and U.S. EPA

Mercury Reduction Progress

In Canada, mercury releases have been reduced by 83 percent from the 1988 baseline. Releases in Ontario have been cut by more than 11,600 kilograms since 1988, based on Environment Canada's 2001 mercury inventory. The largest remaining sources of mercury release in Ontario are electric power generation, incineration, iron & steel production, municipal sector, and cement and lime production.

U.S. mercury emissions decreased approximately 40 percent between 1990 and 1999, according to best estimates from the National Emissions Inventory. It is likely that some additional reductions have occurred since 1999, particularly in emissions from municipal waste combustors and medical waste incinerators. Significant reductions in emissions from these sectors had already taken place by 1999, but compliance with emissions regulations for these categories was not required until after 1999. By 2006, additional regulations and

voluntary activities are expected to reduce mercury emissions a total of 50 percent or more, achieving the reduction challenge.

While U.S. mercury use declined in the late 1990s, progress since 1997 is difficult to gauge quantitatively given changes in the sources of data about mercury consumption. Available data indicate that mercury use declined more than 50 percent between 1995 and 2001; much of this decrease is attributable to decreased mercury use by the chlor-alkali industry, which accounted for an estimated 35 percent of mercury use in 1995. For a more detailed evaluation of data and assessment of progress, see <http://www.epa.gov/region5/air/mercury/progress.html>.

Consumer and commercial products have been significant sources of mercury. Mercury-containing products can include thermometers, switches, dental amalgams, thermostats, button batteries, and fluorescent lamps. Industrial raw materials can also contain unwanted mercury. The elimination of mercury from latex paints and batteries was a significant pollution prevention success of the manufacturing sector in the 1990s. Also, the amount of mercury contained in fluorescent lamps has been reduced.

Numerous mercury reduction activities are occurring in both Canada and the U.S. to meet the GLBTS goals regarding mercury reductions (refer to the GLBTS 2003 Progress Report, available online at www.binational.net). For example, voluntary mercury reduction agreements are being implemented with the chlor-alkali industry and hospitals. For more details and information about other reductions projects and programs check out: <http://www.epa.gov/Region5/air/mercury/mercury.html>.

Regulation of municipal waste, hospital waste, hazardous waste, and sludge incinerators is yielding significant reductions in air emissions of mercury. Canada-wide Standards for these sources have begun to go into effect. Canada-wide Standards have also been developed for the coal-fired Electric Power Generation sector, for mercury-containing lamps, and for dental amalgam waste. These standards are outlined at <http://www.ccme.ca/initiatives/standards.html>) which also provides a broader overview of the Canada-wide Standards process and implementation. In the United States, control standards for small municipal waste combustors were finalized, and compliance is already required at large municipal waste combustors, hospital incinerators, and hazardous waste combustors. Also in the United States, mercury reduction requirements have been finalized in the last two years for mercury cell chlor-alkali plants and iron foundries, and proposed for industrial boilers. Emissions from electric utility boilers, the largest source of mercury emissions in the United States, will be controlled either as a result of a control technology regulation or legislation that controls emissions of mercury along with sulfur and nitrogen. Canada-wide standards are also being developed for this sector.

In June 2001, Pollution Probe, with support from Ontario Hydro, Ontario MOE and Environment Canada, initiated a switch out program to recover mercury switches from end-of-life vehicles. In partnership with the Ontario Automotive Recycling Association the program began with 11 participating auto dismantlers across Ontario. In 2004 the program has grown to include over 130 participating dismantlers in Ontario and has been expanded to other Canadian provinces.

Current Focus of Mercury Reduction Efforts

The GLBTS Mercury Workgroup will continue to focus on information sharing about cost-effective reduction opportunities, tracking of progress toward meeting reduction goals, and publicizing voluntary achievements in mercury reduction. Particular attention will be paid to information sharing in areas where mercury releases are significant but there are no federal regulations existing or regulations are under development. For instance, the workgroup will attempt to focus attention on the contamination of metal scrap by mercury-containing devices, and the resulting emissions, and provide a forum for discussion of cost-effective approaches to address this problem. In addition, the workgroup will focus on the issue of mercury releases from dental offices and will help state, provincial and local governments identify cost-effective reduction approaches for this sector. There will also be a focused discussion of options for minimizing mercury releases resulting from the disposal of mercury-containing lamps.

Table 5.4: Mercury Reduction Plan Activities Update 2004

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
Lake Erie Basin		
Continue to implement Elemental Mercury Collection and Reclamation Program in Ohio (www.bgsu.edu/offices/envhs/environmental_health/mercury/index.htm).	Since the program began in 1998, 7200 lbs of mercury have been removed.	Ohio EPA
Establish a household hazardous waste collection facility to collect and recycle household products containing mercury in the cities of London and Waterloo, Ontario.	COMPLETE Fluorescent lamp collection facilities are available to households in London, Chatham-Kent, Guelph, Brantford, and Wellington County. A Mercury Thermometer Take-Back project was conducted in 2002 in the cities of London (Erie basin), Ottawa, and Thunder Bay. A total of 1.5 kg of mercury was collected.	EC
Continue P3ERIE (Pollution Prevention Partnership & Environmental Responsibility in Erie).	An additional 4,000 pounds of elemental mercury has been collected from businesses, schools, and private citizens in the greater Erie area since 2000. Well over three tons of mercury have been collected and recycled since the inception of the program. Most recently, P3ERIE has initiated a pollution prevention initiative with the PA Dental Association. www.dep.state.pa.us/dep/deputate/pollprev/P3erie/p3erie.htm	
Great Lakes Basin		
U.S. EPA (Air and Radiation Division) has committed funds to support mercury research in a number of priority areas including transport, transformation and fate, and human health and wildlife effects of methyl mercury.	This program provides more than \$1 million per year for research on mercury and other air deposited pollutants in the Great Lakes Basin, focusing on persistent toxic pollutants. Since 2000, projects have been funded to better understand mercury transport, transformation and fate in the environment. Starting in 2003, ARD has (and will in the future) awarded a grant to the Great Lakes Commission to oversee the competition and selection of air deposition research proposals.	U.S. EPA
U.S. EPA filed civil complaints against seven electric utility companies operating coal-fired power plants in the Midwest and Southeast.	U.S. EPA eventually filed a total of nine cases, and has settled two of them, received favorable judgment in one, is awaiting a judge's decision in one, is in discovery on four, and received an unfavorable judgment on another.	U.S. EPA
EPA will continue to focus on research efforts and potential regulation of mercury emissions from coal-fired utilities.	On January 30, 2004, EPA published proposed regulation of the emissions from coal-fired electric utility boilers, the largest source of mercury emissions in the United States. The proposal includes two primary regulatory alternatives. The first is a control technology standard that would achieve 29 percent reduction in mercury emissions by 2009. Under this option, EPA would impose emission rate limits on individual boilers in pounds per megawatt hour of electricity generated. The other option is a two-phase "cap-and-trade" program, ultimately resulting in emissions reductions of 69 percent. This program would be implemented through state plans, under which states would receive mercury emissions "budgets" that they could meet either by setting emissions limits on individual boilers or by distributing mercury emissions allowances. These allowances could be traded with other sources across the country or banked for future use. The first phase of reductions would begin in 2010, with the final phase in 2018.	U.S. EPA

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
Michigan Department of Agriculture: Michigan Mercury Manometer Disposal grant was used to replace mercury manometer gauges used on dairy farms with non-mercury gauges. Mercury was also collected from inactive dairy farms.	COMPLETED. Project Period: 10/1/99 to 9/30/00.	U.S. EPA
Indiana University: Deposition of toxic organic compounds to the Great Lakes. The Integrated Atmospheric Deposition Network Grant provides funds for the operation and maintenance of the Integrated Atmospheric Deposition Network (IADN) by Indiana University.	A new cooperative agreement was awarded to IU for continuation of network through September 2004. Satellite station added at Cleveland in early 2003. New implementation plan for IADN will be signed in 2004.	U.S. EPA
The Integrated Atmospheric Deposition Network Quality Assurance and Quality Control Program Grant. The Great Lakes National Program Office (GLNPO) is collaborating with Environment Canada (EC) to implement the Binational Integrated Atmospheric Deposition Network as mandated by Annex 15 of the Great Lakes Water Quality Agreement and Section 112(m) of the Clean Air Act.	Ongoing.	U.S. EPA and EC
By the end of 2000, the U.S. EPA will work with states to develop a permitting strategy consistent with the Clean Water Act for reducing loading of mercury from industrial, municipal, and storm water sources to further the goals of the LaMP.	COMPLETED. Lake Erie states have developed NPDES mercury permitting strategies that incorporate method 1631 and the new GLI limits and multiple discharger variance rules.	U.S. EPA
U.S. EPA identifies point source dischargers of mercury which are monitored by NPDES permittees using the permit compliance system and shares this information with wastewater treatment plants, industry, tribes and other contributors of mercury to the extent they are relevant sources. U.S. EPA will also inform states and regulated communities about sources of unregulated pollutants of concern and share available information regarding potential substitutes and waste minimization strategies.	U.S. EPA has been using the permit compliance system in working with states on implementation of their permitting strategies and tracking mercury reduction results at permittees.	U.S. EPA
U.S. EPA Region 5 will support the rigorous development and refinement of the Regional Air Toxics Emissions Inventory of all hazardous air pollutants, including those of concern to the Great Lakes and other inland water bodies and which have a tendency to bioaccumulate. U.S. EPA will work closely with all eight Great Lakes states to assure every possible known source of all magnitudes of emissions is identified and that good emissions estimates are developed and updated to reflect the implementation of control technologies and progress in emission reductions for input to air dispersion and deposition models.	U.S. EPA has continued to support development and improvement of emissions inventories through funding for the Regional Air Pollutant Inventory Development System. The RAPIDS project had a specific task to improve the regional emissions inventory for mercury.	U.S. EPA

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
U.S. EPA commits to ensuring that all Region 5 states will have enforceable regulations and the permit applications that are required to be submitted for municipal waste combustors and for hospital/medical/infectious waste incinerators by December 2000.	COMPLETED. U.S. EPA has promulgated regulations controlling emissions of mercury and other Hazardous Air Pollutants from municipal waste combustors (MWCs) and Medical Waste Incinerators (MWIs). Large MWCs needed to be in compliance by December of 2000, while small MWCs will need to comply by December of 2005, at the latest. Compliance was required at MWIs by September of 2002.	U.S. EPA
Canadian federal, provincial and territorial governments to investigate the release of mercury to the environment from various commercial products and some forms of wastes. Focus on dental amalgam, fluorescent lamps and sewage sludge. Expected to result in Canada-wide standards.	COMPLETED. See section 5.5 "Mercury Reduction Progress". Ontario passed Existing Hospitals Regulation (O. Reg. 323/02) requiring all existing hospital incinerators to close by Dec. 6, 2003. Ontario Regulation 196/03 came into effect Nov. 15, 2003 requiring all dental offices in which dental amalgam is placed, repaired, or removed to have a properly installed dental amalgam separator.	EC, MOE
Ontario Ministry of the Environment and EC to work with Ontario Dental Association to develop a "best management practices" document for dentists.	COMPLETED in 2002/03 in partnership with dental profession associations and regulatory bodies, dental colleges and university and provincial and municipal governments.	MOE, EC
Information - Locally Based		
State University of New York at Buffalo: A Mercury Screening Model for Lake St. Clair: This grant supported the development of a model for the state and transport of mercury in Lake St. Clair, where mercury is a well documented problem.	COMPLETED. Project Period: 9/1/99 to 2/28/01.	U.S. EPA
Ohio EPA established the Ohio Mercury Reduction Group in 2001 to reduce the use, release, and emission of mercury in Ohio, to evaluate relevant departmental mercury programs and regulations, collect and assess data, promote the use of mercury alternatives and the collection of retired mercury and products, and educate industry, government and the general public on ways to reduce the sources of mercury in Ohio.	OMRG meets on a monthly basis and has produced fact sheets, an educational video, sponsored thermometer exchanges, shares the latest mercury information, and is working with U.S. EPA on their spill prevention guidance. Along with release of the guidance, OMRG will be working with U.S. EPA to educate every health department in Ohio on mercury spill and P2 information.	Ohio EPA
Information - Lake Erie Basin		
Report on an annual basis, the status of sediment remediation at priority sites within the Lake Erie basin.	See Binational Toxics Strategy Annual Report at www.binational.net	U.S. EPA and EC

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
If on-going long-range sources of mercury to the Great Lakes are confirmed, work within international frameworks to reduce releases.	In 2003, the United Nations Environment Programme (UNEP) established the new global Mercury Programme. Both Canada and the United States are participating in the Mercury Programme, which has urged all countries to adopt goals and take actions, as appropriate, to identify populations at risk and to reduce human-generated releases. The UNEP Mercury Programme will provide capacity building and technical assistance to help countries better characterize and address their mercury problems. The U.S. EPA and Environment Canada, with the support of the Commission for Environmental Cooperation, the International Joint Commission, and the Delta Institute, held a workshop on the long-range transport of toxic substances to the Great Lakes. The commissioned background paper, the workshop's program, the workshop presentations, and the draft summary document are available on the Internet at: http://www.delta-institute.org/lrtworkshop/open.html .	U.S. EPA and EC
Develop a pollution prevention web page at www.deq.state.mi.us/ead/p2sect/mercury and distribute mercury outreach materials to science teachers.	COMPLETE. The Michigan Department of Environmental Quality's (MDEQ's) environmental coordinator conducted a mass mailing of Pollution Prevention (P2) materials to all Michigan Intermediate School Districts. The "Science Teachers" and "Merc Concern" brochures were featured, along with a new publication titled "The P2 Education Tool Box".	Michigan and U.S. EPA
Lake Erie Public Forum targeted fish advisory materials and website in cooperation with the Lake Erie Binational Public Forum.	The Lake Erie Public Forum created easy to read and culturally sensitive fish advisory brochures to reach at risk populations. They were distributed at events likely to be frequented by minorities or lower income target populations. Information is also available on the Lake Erie Forum website, maintained by the Delta Institute, at www.erieforum.org/fishguide/fishguide.php . This project is ongoing.	Lake Erie Forum
EPA Superfund commits to completing maps including data on location of sensitive species, tribal lands, natural areas, managed lands, economic resources and potential spill sources and providing these maps to LaMP/RAP partners by the end of FY 2002.	Maps were completed for western Lake Erie and the Cleveland area. They are part of the Inland Area Sensitivity Atlas prepared as required under the Oil Pollution Act of 1990. See www.umesc.usgs.gov/epa_atlas/overview.html	U.S. EPA
Promote the Great Art for Great Lakes Virtual Classroom, with its mercury millennium theme, in primary schools in the Lake Erie basin.	COMPLETE	
Promote to school boards in the Lake Erie basin a mercury stewardship school curriculum program.	Project materials and workshops were delivered in over 20 schools across the Thames Valley District School Board and London District Catholic School Board.	EC
Information - Great Lakes Basin		
Ohio's Office of Pollution Prevention will produce two fact sheets that focus on ways to reduce mercury and other PBTs.	Ohio EPA has produced 4 mercury fact sheets, a mercury web page and a mercury educational video. www.epa.state.oh.us/opp/mercury_pbt/mercury.html	Ohio EPA
U.S. Navy, Great Lakes Naval Station, Naval Dental Research Institute: Mercury Removal from the Dental-Unit Waste Stream – The interagency agreement provides funds to the Naval Dental Research Institute to examine the mercury removal from dental unit wastewater stream. Project Period: 9/1/99 to 8/31/00.	COMPLETE. The Great Lakes Naval Dental Research Institute continues to pursue this research with funding from U.S. EPA's Great Lakes National Program Office.	U.S. EPA

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
The Delta Institute Sector Based Pollution Prevention – The Delta Institute will focus on achieving reductions through commitments from the private and public sector owned and operated energy production units. Project Period: 10/1/99 to 9/30/00.	In July of 1999, the Delta Institute launched a partnership with the Council of Industrial Boiler Owners to achieve emission reductions of GLBTS Level I and Level II pollutants from industrial boilers through the implementation of selected energy efficiency technologies and methods. Delta undertook a study that found that a 10% improvement in energy efficiency to the 1531 coal burning industrial boilers and 1436 residual fuel oil burning boilers in the Great Lakes basin would result in a mercury emissions reductions of 443 lbs and 389 lbs respectively. Delta and CIBO are working with EPA, MDEQ and Ohio EPA to launch a national energy efficiency campaign for industrial boilers. More information can be found at http://delta-institute.org/pollprev/ibp.php	U.S. EPA
National Wildlife Federation: Local and sector based Pollution Prevention in the Binational Strategy – The National Wildlife Federation will focus on 1) building one existing efforts to implement pollution prevention, by way of sector-based strategies; and 2) coordinated environmental non-governmental organization participation in the Binational Toxics Strategy. Project Period: 10/1/99 to 9/30/00.	COMPLETE. NWF continues to participate in the GLBTS and pursue this work.	U.S. EPA
Ohio Healthy Hospital Pollution Prevention Initiative	A formal agreement was signed between Ohio EPA and the Ohio Hospitals Association in 1999 to develop and implement a strategy to virtually eliminate and OHA mercury and mercury-containing waste from the health care industry's waste stream by 2005. A mercury challenge handbook has been prepared as well as a web page and the program continues. See: www.epa.state.oh.us/opp/hospital.html	Ohio EPA
U.S. EPA will assist utilities in developing mercury control technology. Assistance may not take the form of funding.	U.S. EPA and the Department of Energy have participated in several projects to develop "clean coal" technology.	U.S. EPA
Agencies will work with communities to provide sector-specific pollution prevention outreach such as workshops for the medical and dental communities, and other important sectors.	<p>Canada: Online pollution prevention information to assist health care professionals is available at www.c2p2online.com Seminars on environmental programs, products and services were held during the Ontario Hospital Assoc. convention November 2002.</p> <p>Mercury thermometer take-back programs held at hospitals associated with the Cdn Coalition for Green Health Care. Green Healthcare workshop held in September 2003.</p> <p>U.S.: Chlor-alkali industry, through the Chlorine Institute, committed in 1996 to reduce mercury use 50 percent by 2005. The industry reported in April 2003 that they achieved 50% reduction in mercury use between 1995 and 2002. The American Hospital Association and U.S. EPA through the Hospitals for a Healthy Environment (H2E) program have produced a Mercury Virtual Elimination Plan for U.S. hospitals. In addition, workgroups are implementing work plans on various aspects of hospital waste reduction. U.S. EPA and Environment Canada held a workshop on dental mercury reductions for state and local governments in December of 2002. A report was produced, based on this workshop.</p>	<p>EC</p> <p>U.S.EPA</p>

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
U.S. EPA will encourage proper management of dental wastes that contain mercury.	U.S. EPA continues to fund dental mercury waste projects through the GLNPO Pollution Prevention and Toxics Reduction grant program and Regional PPIS grants. A grant was awarded to Erie County (NY) in 2003. A grant was awarded to Delta Institute to work with the cities of Solon and Elyria (OH) to reduce the input of mercury from medical and dental sectors into the waste stream of wastewater treatment plants. The project is ongoing.	U.S.EPA
U.S. EPA will track the disposition and of the U.S. Federal Government's mercury stockpiles.	COMPLETE. U.S. EPA has tracked the Defense Logistics Agency's development of an Environmental Impact Statement on the mercury stockpiles, which has been released in draft form. DLA has proposed a preferred option of long-term storage of the stockpile.	U.S.EPA
Agencies will assist schools in seeking out and disposing of mercury on school property.	The Michigan Department of Environmental Quality's (MDEQ's) environmental coordinator conducted a mass mailing of Pollution Prevention (P2) materials to all Michigan Intermediate School Districts. The "Science Teachers' and "Merc Concern" brochures were featured, along with a new publication titled "The P2 Education Tool Box".	U.S.EPA and Michigan
The Great Lakes Binational Toxics Strategy should be pursued to meet the short term, interim goals (e.g., 50% reduction in mercury U.S. sources and emissions by 2006 and for Canada, a 90% reduction in the release of mercury from polluting sources by 2000).	See Section 5.5 portion titled "Mercury Reduction Progress" and "Current Focus of Mercury Reduction Efforts."	U.S.EPA and EC
Sampling will begin in 2000 for the National Study of Chemical residues in lake fish tissue, a new effort to develop a national picture of the distribution of a variety of potential fish contaminants in the Nation's lakes. Bioaccumulative organic chemicals and mercury will be analyzed.	Sampling has been completed and a final report is due out by the end of FY2004.	U.S.EPA Region 5
U.S. EPA will complete the pilot projects to establish TMDL allocations for two waterbodies receiving mercury from atmospheric deposition in order to evaluate the integration of air and water program technical tools and authorities and to examine emission reduction options.	U.S. EPA Headquarters is currently reviewing a proposal from the ECOS Quicksilver Workgroup on developing alternatives to TMDLs for mercury. Once the proposal is finalized, Region 5 will be working with states to develop either this alternative or to develop TMDLs.	U.S.EPA Region 5

5.6 Emerging Chemicals

The LaMP has recognized that emerging chemicals may impact on the LaMP's vision of a sustainable Lake Erie ecosystem and that a process is needed to evaluate the potential impacts, sources, and remediation options for emerging chemicals. The LaMP will be looking to the Great Lakes Binational Toxics Strategy, as the experts in persistent toxic substance reduction, to identify potential emerging chemicals of concern in the Great Lakes. The Great Lakes Binational Toxics Strategy has committed to developing an *Emerging Pollutants Evaluation Protocol* to evaluate the impacts of specific emerging pollutants in the Great Lakes.

The LaMP's Sources and Loads Subcommittee anticipates updating the list of critical pollutants and pollutants of concern over the next two to three years. A review of the beneficial use impairments (BUIs), together with information about the potential causes

of those BUIs, will be used to assess whether changes in status of the existing pollutants of concern and/or critical pollutants are warranted, or whether new compounds should be elected to these lists.

5.7 Future Directions

The binational sediment mapping of critical pollutants and pollutants of concern has been completed (see Section 5.2). A report is in preparation by the U.S. Geological Survey (USGS) outlining the methodology and results of the sediment mapping initiative, including an overview of contaminated sites in the basin, an assessment of spatial trends, and recommendations for future directions in the management of contaminated sediments. The report will also include a summary of the findings of the sediment workshop held in 2002 in which experts from across the basin met to discuss the status of sediment contamination, assessment and remediation projects in the Lake Erie basin.

Through the United States Geological Survey, the Sources and Loads Subcommittee is also currently undertaking a basin-wide initiative to map fish tissue contaminant data, similar to the sediment mapping effort. Fish species that migrate over relatively small areas are being selected so that spatial trends can be assessed in a meaningful way across the Lake Erie basin. Possible relationships in the spatial trends between the fish tissue and sediment quality data will be examined. Differences between the different agencies' fish collection procedures and analytical methods may make some data comparison difficult, but it is anticipated that this information compilation will result in a unique, basin-wide view of the status of fish contamination. A report of this initiative is anticipated during 2004.

In addition to providing technical reports of the results of the mapping initiatives, we anticipate some more informal reporting to the Remedial Action Plans (RAPs) to proceed during 2004. The RAPs may be interested to know how the contaminant status within their particular area of concern (AOC) compares with other AOCs. As a communication tool, the Sources and Loads Subcommittee will also be calculating a Sediment Quality Index (SQI) for the sediment quality data across the basin. The SQI compares the sediment quality data to existing environmental guidelines, and is used to calculate an overall index that rates the sediment quality as excellent, very good, good, fair or poor. In this way, the overall sediment quality can be viewed in a nutshell, across the basin, without having to assess information from the maps of the sediment quality compounds individually.

An analysis of source information in the basin will form the next priority for this Subcommittee. Both the U.S. and Canadian environmental agencies compile and maintain information about discharges of contaminants to the environment. The available information will be compiled on a binational basis and compared with the environmental quality information already examined in order to assess if monitoring gaps exist (e.g., sources with no nearby monitoring data) or if there are sites of unexplained environmental quality (e.g., hot spots with no known sources). The Subcommittee is also aligning itself to better coordinate with the Great Lakes Binational Toxics Strategy (GLBTS) in order to follow up on source reduction activities and remediation activities.

5.7.1 Evaluation of Pollutant Release Inventories and Permit Systems

Over the next year, the Lake Erie LaMP Source and Loads Subcommittee will be evaluating national datasets that provide estimated and measured releases of critical and priority pollutants within the Lake Erie Basin. The Toxic Release Inventory (TRI) and the Permit Compliance System (PCS) will be evaluated in the United States, while the National Pollutant Release Inventory (NPRI) and Ontario's Municipal/Industrial Strategy for Abatement (MISA) will be evaluated in Canada.

Although useful in many ways, the TRI and NPRI have various limitations and do not capture data for all substance releases into the basin. In particular, the criterion for reporting to these programs is such that numerous smaller sources are not captured. Also, reported releases are not always measured, but may in fact be estimates. Reporting criteria have evolved over the years, requiring new sectors to report; substances have been added or

reporting thresholds for existing substances have changed. These ongoing changes make it more difficult to interpret the overall database through time. The data that is of greatest value to the Lake Erie LaMP are the on-site releases to air, water, and land, as well as off-site transfers of substances to sewage treatment plants. Releases to land include those contaminants disposed on-site to sanitary or hazardous waste landfills, as well as land surface applications and holding pits. Releases reported within the Lake Erie Basin do not necessarily imply that they are directly discharged to Lake Erie, nor that these contaminants are physically or biologically available to biota within the Basin; however, it is an adequate representation of sources and releases of available or potentially available contaminants.

Figures 5.11 and 5.12 show the top 10 contributing industries for releases of mercury and mercury compounds to land (including on-site landfills), off-site transfers to sewage treatment plants, and releases to air and water, respectively, over an eight year period (1995-2003) within the Lake Erie Basin. During that period, over 69,000 kg (151,800 lbs) of mercury were reported released or transferred to the basin: approximately 29,200 kg (64,000 lbs) to sewage treatment; 19,900 kg (43,780 lbs) to air, 20,000 kg (44,000 lbs) to land, and 168 kg (370 lbs) directly to water. Companies certified to deal with sanitary and hazardous waste were the top contributors followed by electric generating plants and chlor-alkali plants. Other contributors were manufacturers of industrial chemicals, paper, steel, mineral products, electric lamps, hoses and belts, and cement.

Figures 5.13 and 5.14 show the top contributors of PCBs to the environment as reported by TRI over the same eight year period. The NPRI program in Canada does not require reporting for the release of PCBs. Over 758,000 kg (1.7 million lbs) of PCBs were disposed of at on-site hazardous waste landfills and storage facilities within the Basin, representing 99% of the total PCBs released. Five kg (11 lbs) were released to sewage treatment, and 310 kg (680 lbs) were released to the air. No PCBs were reported discharged directly to water. As was the case for mercury, waste management companies were the top contributors as a secondary handler of PCBs transferred from other facilities for the purpose of treatment/disposal. Manufacturers of abrasive products were the greatest contributor of PCBs to the air with 160 kg (352 lbs).

A detailed summary of the bed-sediment, related fish tissue and industrial emissions data analyzed for use in the LaMP 2006 report will be published by USGS in 2007.

Figure 5.11: Mercury and its compounds - Top 10 industries reporting onsite releases to land and transfers to sewage treatment plants within the Lake Erie Basin. (Toxic Release Inventory (TRI) and National Pollutant Release Inventory (NPRI), 1995-2003)

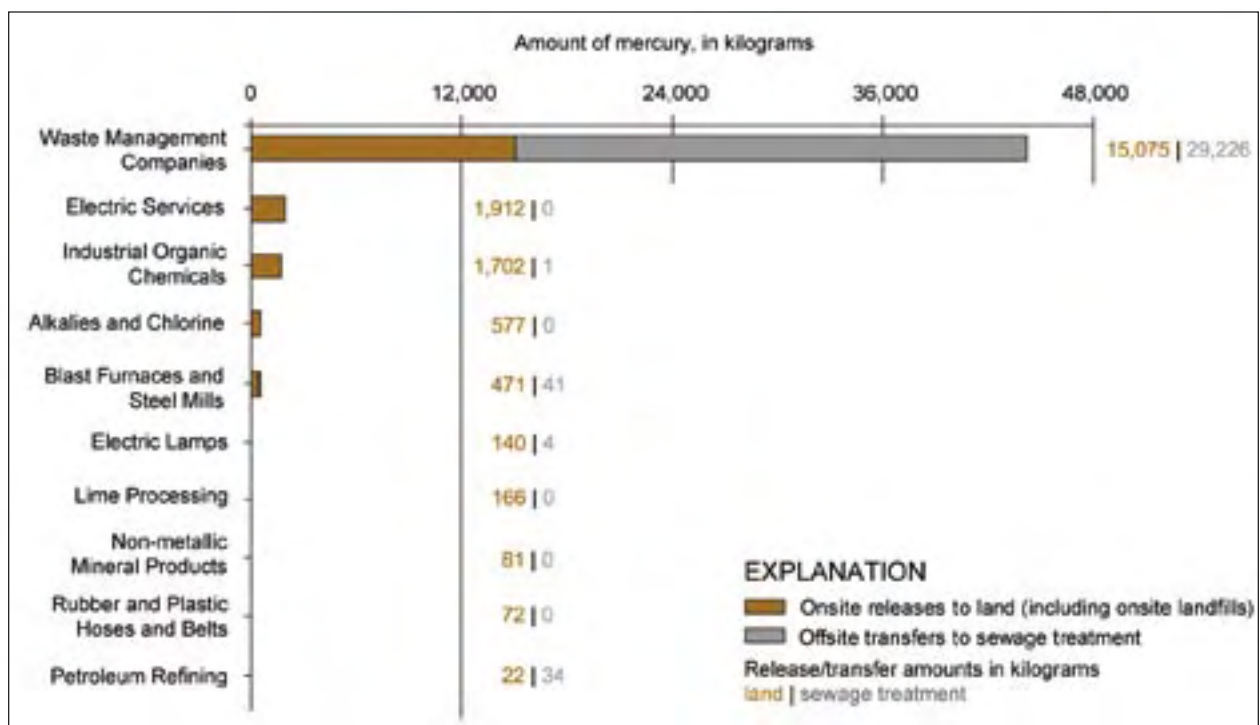


Figure 5.12: Combined estimated mercury onsite releases to air and water within the Lake Erie Basin for the top 10 contributing U.S. and Canadian industries. (Toxic Release Inventory (TRI) and National Pollutant Release Inventory (NPRI), 1995-2003)

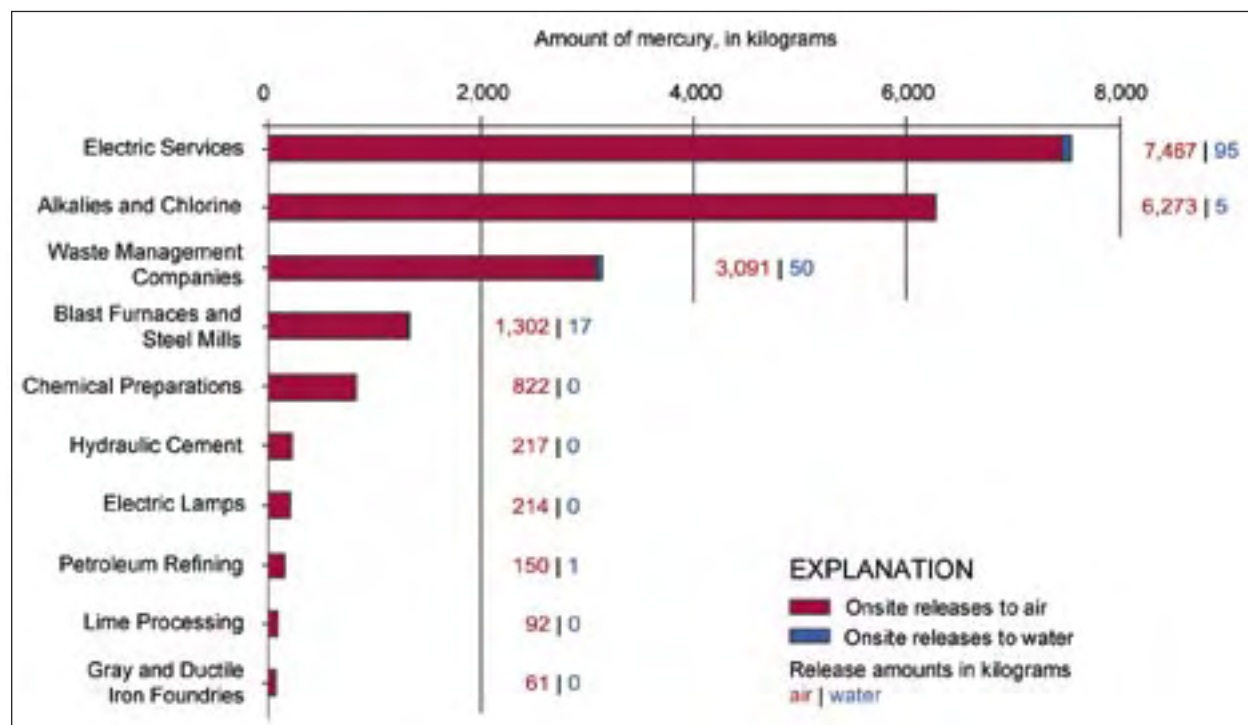


Figure 5.13: Polychlorinated biphenyls (PCBs) - Industries reporting onsite releases to land and transfers to sewage treatment plants within the Lake Erie Basin. (Toxic Release Inventory (TRI), 1995-2003)

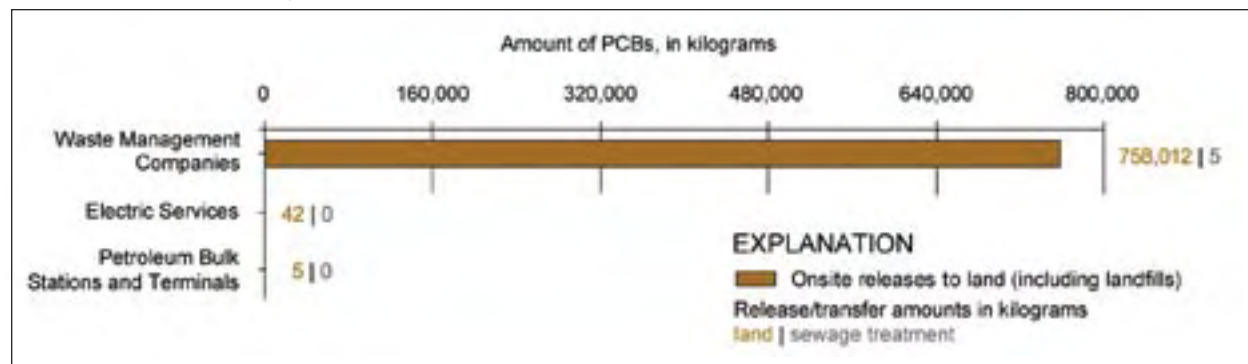
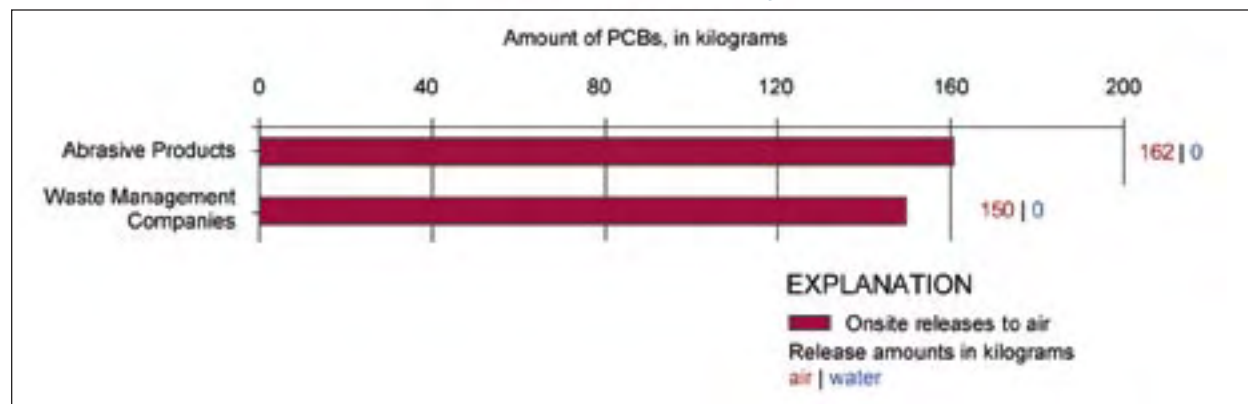


Figure 5.14: Polychlorinated biphenyls (PCBs) - Industries reporting onsite releases to air and water within the Lake Erie Basin. (Toxic Release Inventory (TRI), 1995-2003)



5.8 References

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